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UNITED STATES AIR FORCE ARMSTRONG LABORATORY

Guidance Document For Control Of Microbiological Growth In An Air Force Base Water Distribution Systems

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This technical report has been reviewed by the Public Affairs Office and is releasable to the National Technical Information Service, where it will be available to the general public, including foreign nationals.

This report has been reviewed and is approved for publication.

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In recent years, a lack of proper control, maintenance, and management of base water systems has resulted in an increased period of bacteriological noncompliance in the distribution system. Armstrong Laboratory (AL) has conducted some limited case studies of such violations of Safe Drinking Water Act (SDWA) Regulations. The objective of this guidance document is to assist Air Force Civil and Bioenvironmental Engineers (CE/BEE) in operating and maintaining water distribution systems to avoid distribution system water quality violations of SDWA Regulations and to develop corrective actions.

The report provides a summary of requirements of various existing SDWA Regulations that have impacts on distribution water quality, such as Surface Water Treatment Rule (SWTR) and Total Coliform Rule , as well as potential future rules, such as Information Collection Rule (ICR) and Disinfectant/Disinfection By-Products Rule (D/DBP). An action plan has been developed describing bacteriological sampling requirements of TCR and possible corrective actions to avoid noncompliance. A systematic methodology has been described to develop a comprehensive maintenance program to improve general water quality in distribution systems, and a case study has been conducted to illustrate the methodology.

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PREFACE

This report summarized project activities conducted by Roy F. Weston, Inc. for Resource Applications, Inc., under Armstrong Laboratory Contract No. F49650-91-D-0008, Task Order 0063-02, *Guidance Document for Control of Microbiological Growth in Air Force Base Water Distribution Systems* during the performance period March 1995 through July 1996.

The work summarized in this report has been conducted by Arun K. Deb of Roy F. Weston, Inc., and Captain Franz J. Schmidt of Armstrong Laboratory, Water Quality Branch (AL/OEBW) was the Project Officer.

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LIST OF ABBREVIATIONS AND ACRONYMS

ADF	Average daily flow
AETC	Air Education and Training Command
AF	Air Force
AFB	Air Force Base
AFCEE	Air Force Center for Environmental Excellence
AFCESA	Air Force Civil Engineering Support Agency
AFI	Air Force Instruction
AFM	Air Force Manual
AFMC	Air Force Materiel Command
AFOSH Stds.	Air Force Occupational Safety and Health Standards
AFR	Air Force Regulation
AL	Armstrong Laboratory
AL/OEA	Armstrong Laboratory Occupational and Environmental Health Directorate, Analytical Services Division
AL/OEB	Armstrong Laboratory Occupational and Environmental Health Directorate, Bioenvironmental Engineering Division
AOC	assimable organic carbon
AWWA	American Water Works Association
BCE	Base Civil Engineer
BCRWA	Bay County Regional Water Authority
BE	Bioenvironmental Engineering
BES	Bioenvironmental Engineering Services
C	Concentration
CE/BEE	Air Force Civil and Bioenvironmental Engineers
cfu	colony-forming unit (bacterial inocula)
COC	Chain of Custody
CT	disinfection contact time
D/DBP	Disinfection/Disinfectant By-Products Rule
DBP	disinfectant by-product
DBMS	Director of Base Medical Services
DOC	dissolved organic carbon
E. coli	*Escherichia coli*
EPA	U.S. Environmental Protection Agency
ESWTR	Enhanced Surface Water Treatment Rule
fps	feet per second
ft	foot/feet
GAC	granular activated carbon

LIST OF ABBREVIATIONS AND ACRONYMS
(Continued)

GIS	geographic information system
GWDR	Groundwater Disinfection Rule
gpm	gallons per minute
HAAs	haloacetic acids
HDPE	high-density polyethylene
HPC	heterotrophic plate count
ICR	Information Collection Rule
IOCs	inorganic chemicals
kPa	Kilo Pascal
m/s	meter per second
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
MF	membrane filtration
mgd	million gallons per day
mg/L	milligrams per liter
mL	milliliter
mm	millimeter
MTF	multiple tube fermentation
NCO	Noncommissioned Officer
NOV	Notice of Violations
NPDWRs	National Primary Drinking Water Regulations
P-A	positive acid
psi	pounds per square inch
PVC	polyvinyl chloride
QA	quality assurance
QC	quality control
SDWA	Safe Drinking Water Act
SG	Surgeon General
SMCLs	secondary maximum contaminant levels
SOCs	synthetic organic compounds
SWTR	Surface Water Treatment Rule
TAFB	Tyndall Air Force Base
TC	total coliform
TCR	Total Coliform Rule
THMs	trihalomethanes
TNTC	too numerous to count
TOC	total organic carbon
VOCs	volatile organic compounds
µg/L	micrograms per liter

SECTION 1

INTRODUCTION

Most of the approximately 87 major Air Force (AF) installations were constructed during World War II. A few were constructed prior to World War II during the early 1900s. Base military and civilian populations generally range from 3,000 to 10,000 people. Ten of these installations have populations ranging between 10,000 and 30,000 people.

During the last two decades, the water systems serving the installations have aged and have experienced large numbers of main breaks resulting in loss of water, an increase in water quality problems, and expensive repairs to broken water mains. Increasingly stringent water quality regulations have resulted in violations of the National Primary Drinking Water Regulations (NPDWRs).

The water systems serving these AF installations must comply with all state and federal drinking water regulations. The state agencies (usually the Department of Health or Environmental Protection) have primacy for the administration of the federal regulations. Primacy is a process whereby the states have met stringent requirements of the United States Environmental Protection Agency (EPA) and have been granted the right to administer the federal regulations. These state agencies also enforce their own state's regulations which can sometimes be more stringent than the federal regulations. The age of the systems coupled with deferred maintenance in an atmosphere of increasing regulation have resulted in many "Notice of Violations" (NOVs).

Because of increased NOVs at AF installations in recent years, resulting from distribution system microbiological growth, AL/OEB is receiving increased requests for assistance to avoid future NOVs. Historical records indicate that many of these NOVs are related to poor performance of the water distribution systems. AL/OEB has developed this guidance document for AF installations to use in developing routine short-, intermediate-, and long-term maintenance programs for their distribution systems.

The AF developed the Air Force Occupational Safety and Health Standard (AFOSH Std 48-6), by order of the Secretary of the Air Force, to manage and maintain AF drinking water systems. Primary responsibility for operating and maintaining the AF water systems lies with the Base Civil Engineer (BCE) and the Director of Base Medical Services (DBMS) through the Bioenvironmental Engineer (BEE). The BCE is responsible for design, construction, operation, and maintenance of the base water system. The BEE is responsible for water quality monitoring and compliance. Table 1-1 shows primary responsibilities of the BCE and the BEE. Figure 1-1 is a graphical presentation and summary of the management of, and responsibilities for, the overall AF Drinking Water Program.

Table 1-1

Primary Responsibilities of the BCE and BEE

BCE Responsibilities	BEE Responsibilities
• Design, construct, maintain, and operate water distribution systems. • Coordinate water distribution system operation and maintenance activities (such as water main breaks and repairs, water main rehabilitation/replacement, flushing of mains, monitoring, etc.) with BE. • Perform the cross-connection control and backflow prevention maintenance program and training. • Assists with sanitation survey. • Perform water main disinfection - new and repaired. • Implement flushing and valve maintenance program. • Update base utility maps.	• Maintain compliance with potable water regulations. • Execute base monitoring program. • Performs sanitary survey. • Interpret water analyses reports. • Maintain map of sampling locations. • Coordinate water sampling monitoring, compliance activities, and other water quality related work with the base CE. • Update annually comprehensive monitoring plan. • Oversee Cross-connection control and backflow prevention program and training.

The following sources of support and help are available to AF installations in operating and maintaining drinking water systems:

- **AL Bioenvironmental Engineering Division (AL/OEB)** provides consultative assistance in solving water quality problems, including field surveys, sampling, compliance issues, and technical consulting.

- **Air Force Civil Engineering Support Agency (AFCESA)** provides help in the areas of base water systems operations and maintenance, development of water resources, and treatment.

- **AL Analytical Services Division (AL/OEA)** provides services for analysis of drinking water samples and is responsible for water quality data repository of all AF installations that utilize these services.

While the AFOSH Std. 48-6 outlines specific responsibilities of the BCE and BEE, many responsibilities are not being conducted routinely because of a lack of properly trained and experienced personnel. For example, the following functions are not performed regularly in most AF installation water systems:

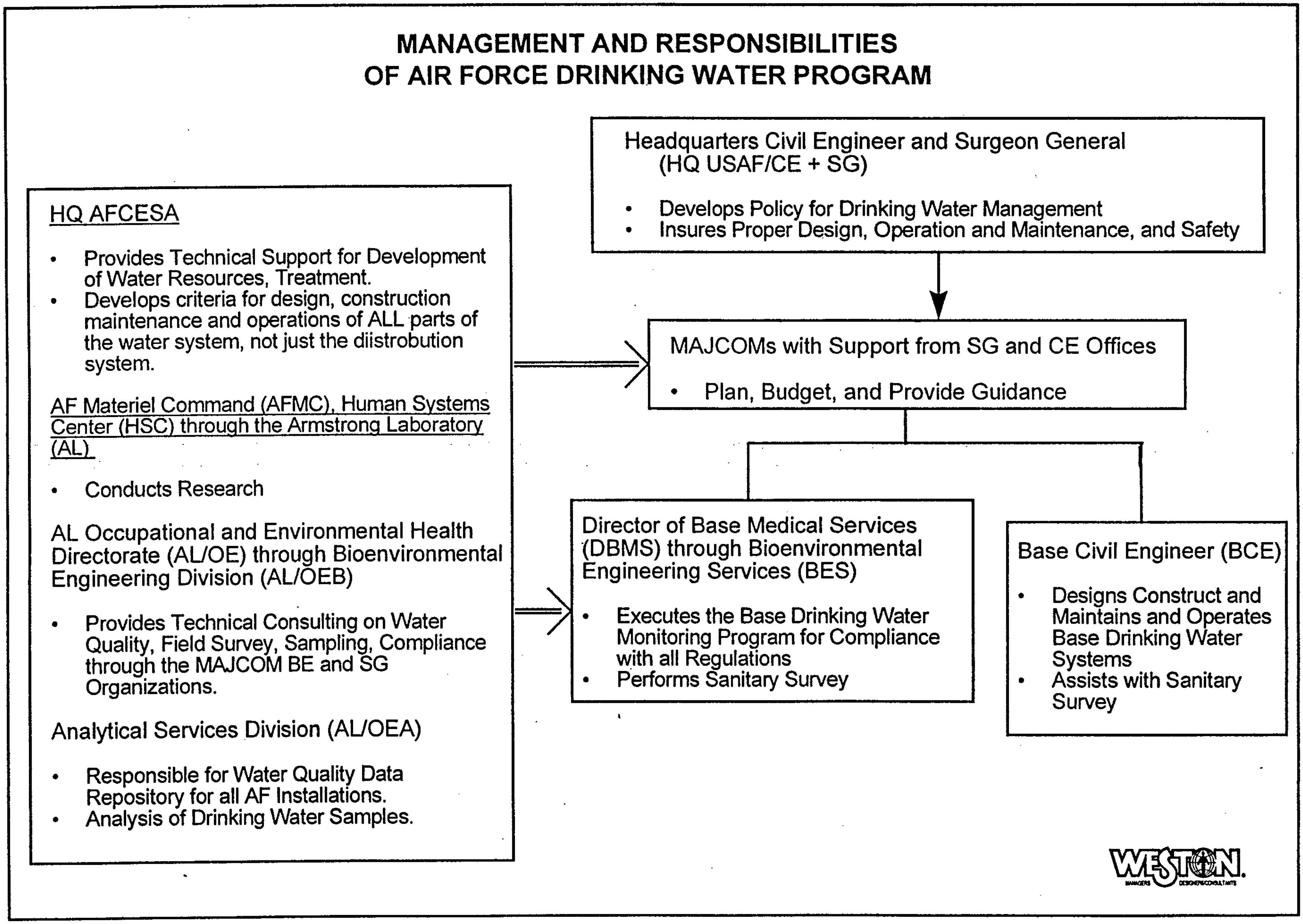

MANAGEMENT AND RESPONSIBILITIES
OF AIR FORCE DRINKING WATER PROGRAM
Headquarters Civil Engineer and Surgeon General
(HQ USAF/CE + SG)
• Develops Policy for Drinking Water Management
• Insures Proper Design, Operation and Maintenance, and Safety
MAJCOMs with Support from SG and CE Offices
• Plan, Budget, and Provide Guidance
Director of Base Medical Services (DBMS) through Bioenvironmental Engineering Services (BES)
• Executes the Base Drinking Water Monitoring Program for Compliance with all Regulations
• Performs Sanitary Survey
Base Civil Engineer (BCE)
• Designs Construct and Maintains and Operates Base Drinking Water Systems
• Assists with Sanitary Survey
HQ AFCESA
• Provides Technical Support for Development of Water Resources, Treatment.
• Develops criteria for design, construction maintenance and operations of ALL parts of the water system, not just the diistrobution system.
AF Materiel Command (AFMC), Human Systems Center (HSC) through the Armstrong Laboratory (AL)
• Conducts Research
AL Occupational and Environmental Health Directorate (AL/OE) through Bioenvironmental Engineering Division (AL/OEB)
• Provides Technical Consulting on Water Quality, Field Survey, Sampling, Compliance through the MAJCOM BE and SG Organizations.
Analytical Services Division (AL/OEA)
• Responsible for Water Quality Data Repository for all AF Installations.
• Analysis of Drinking Water Samples.
WESTON

FIGURE 1-1

- Performance of sanitary surveys (every 5 years).

- Implementation and enforcement of cross-connection control and backflow prevention programs.

- Disinfection of new and repaired water mains.

- Implementation of a water system flushing program.

- Maintenance of sampling location maps and an up-to-date, comprehensive monitoring program.

- Evaluation, resolution, and management of customer complaints.

This lack of proper control, maintenance, and management of base water systems has resulted in an increased period of bacteriological noncompliance in water distribution systems. During the summer months, many AF installation water systems are having Total Coliform Rule (TCR) violations. The TCR based maximum contaminant level (MCL) for coliform is more stringent than previous coliform regulations because it is based on the presence or absence of total coliforms rather than the previous standard, which was based on a density determination. As a result, the new regulation is much more stringent than the previous regulation and requires tighter control of water quality in the distribution system to maintain system compliance. The TCR is one of the most important regulations to control bacteriological water quality; it requires prompt actions to be taken in case of violations.

In recent years, concerns have been raised regarding the deterioration of water quality while it is transported through the distribution system. The Surface Water Treatment Rule (SWTR) requires water systems to maintain a specified residual concentration (C) of a disinfectant at all locations in the distribution system. The disinfectant concentration C in milligrams per liter (mg/L) multiplied by the contact time T, in minutes, is known as the "CT" value. The "CT" value, in conjunction with pH and temperature, is used as a measure of the amount of disinfection and the resulting "kill" of coliforms in the water system.

The TCR requires monitoring of water at specified locations in the distribution system for total coliform and residual chlorine. A positive measurement of total coliform and absence of residual chlorine requires confirmatory sampling and implementation of appropriate corrective actions. The SWTR and TCR have tremendous impact on monitoring and maintenance of bacteriological water quality in a distribution system.

Armstrong Laboratory (AL) has conducted some limited case studies of violations of the TCR and SWTR at AF installations and has developed this guidance document to help Air Force Civil and Bioenvironmental Engineers (CE/BEE) operate and maintain distribution systems to avoid violations of TCR and SWTR and to develop corrective actions.

Report Format

The objective of this guidance document is to assist the Air Force Civil and Bioenvironmental Engineers (CE/BEE) in operating and maintaining water distribution systems to avoid water quality violations of the Safe Drinking Water Act (SDWA). This report consists of the following information:

- Section 1 provides background information and a brief discussion of management of water distribution systems at Air Force installations.

- Section 2 provides a summary of requirements for existing SDWA regulations that impact water distribution systems, including the SWTR and the TCR and discusses potential future rules, such as the Information Collection Rule (ICR) and the Disinfectant/Disinfection By-Products (D/DBP) Rule.

- Section 3 provides an action plan to comply with the requirements of the TCR and possible corrective actions to avoid noncompliance.

- Section 4 provides a methodology for developing a comprehensive maintenance program to improve microbiological water quality in distribution systems.

- Section 5 presents a case study of the Tyndall Air Force Base (TAFB) water system.

- Section 6 provides a listing of Air Force Regulations and other information resources that each Air Force Base should maintain.

- Appendix A presents a glossary of terms.

- Appendix B is a listing of SDWA contaminants.

SECTION 2

FEDERAL DRINKING WATER REGULATIONS

This chapter provides an overview of the current Federal Drinking Water Regulations with further discussion of the SWTR, TCR, D/DBP, and ICR.

2.1 OVERVIEW

The SDWA, as amended in 1986, requires EPA to promulgate NPDWRs, which specify MCLs or treatment techniques for drinking water contaminants. NPDWRs apply only to public water systems, i.e., those systems that have 15 or more service connections or regularly serve at least 25 people for 60 or more days per year. The regulations further classify public water systems into community systems (those that serve a resident population) and noncommunity systems (those serving nonresident populations). Noncommunity water systems are further classified into nontransient systems (serve the same nonresident population, such as schools and factories) and transient systems (serve different nonresident populations, such as highway rest stops and motels).

To date, EPA has promulgated NPDWRs for a variety of volatile organic compounds (VOCs), fluoride, coliform and other microbiological contaminants, several synthetic organic compounds (SOCs) and inorganic chemicals (IOCs), radionuclides, and lead and copper. Standards for additional VOCs, SOCs, IOCs, radionuclides, and disinfectant by-products (DBP) are expected to be promulgated over the next few years.

For most of the regulated compounds, an MCL and maximum contaminant level goal (MCLG) have been established. While MCLs are enforceable standards that must be met by all systems, MCLGs are nonenforceable recommended health goals. Additionally, unenforceable federal Secondary Drinking Water Standards have been promulgated for compounds that affect the taste, odor, color, and certain other aesthetic characteristics of drinking water. Individual states may, however, adopt recommended secondary maximum contaminant levels (SMCLs) as enforceable standards.

A standardized monitoring framework has been developed for source-related contaminants associated with chronic health effects. These include VOCs, pesticides, radionuclides, and most inorganic chemicals. All public water systems will be subject to a 9-year cycle, divided into three 3-year compliance periods. Beginning in 1993, all compliance cycles and compliance periods began operating on a calendar-year basis (1 January to 31 December).

The SDWA has been promulgated in several phases and additional phases are proposed for promulgation in the near future. Each phase regulates one or more groups of compounds. Table 2-1 contains a summary of these phases. Appendix B presents a detailed listing of contaminants contained in each phase.

Table 2-1

SDWA Contaminant Summary

Phase	Description
I	Compliance with MCLs for 8 specified VOCs. Monitoring for 37 other organic compounds.
II	Compliance with MCLs for 10 VOCs, 9 IOCs, and 15 SOCs. Monitoring for 11 organic compounds. Treatment techniques for 2 compounds.
III	Proposed regulation of 12 radionuclides.
V	Compliance with MCLs for 3 VOCs, 5 IOCs, 6 organics, and 9 pesticides.
VIa	Proposed regulation of 3 disinfectants, 3 inorganics, and 9 organics disinfectant by-products.
VIb	Proposed regulation of 4 inorganic and 10 organic compounds.

Source: *Safe Drinking Water Management Action Plan for Seymour Johnson AFB,* 1995, EA Engineering, Science, and Technology, Inc.

2.2 SURFACE WATER TREATMENT RULE (SWTR)

The SWTR was promulgated on 29 June 1989 and sets new standards for treatment of surface water and groundwater under the influence of surface water. Its goal is the reduction of *Giardia* and viruses by 3-log and 4-log, respectively (99.9% and 99.99% removals). Removal of *Giardia* and viruses will also result in removal of other pathogens. Removal of *Giardia* and viruses is achieved by maintaining specified "CT" values in the distribution. SWTR requires each system to evaluate disinfection concentration and contact times and to maintain specified "CT" values depending on disinfectant chemical, pH, and temperature of water.

The SWTR set turbidity performance criteria for determining the efficiency of the treatment plant solids removal steps, i.e., sedimentation and filtration. In addition, a minimum chlorine residual level of 0.2 mg/L for water entering the distribution system must be maintained. Chlorine residual also must be maintained in at least 95% of all distribution system samples.

2.3 TOTAL COLIFORM RULE (TCR)

This section contains a summary of the requirements of the TCR. Since the development of an action plan to minimize coliform contamination of the distribution system is the primary focus of this report, the different aspects of the TCR will be discussed in detail.

The TCR has a significant impact on base water systems. This is primarily due to the stringent MCL for total coliforms, fecal coliforms, and *Escherichia coli (E. coli),* as well as the stringent public notification requirements.

2.3.1 Coliform Standard

The MCLG for total coliforms is zero. The MCL is based on the presence or absence of total coliform. This rule requires that water systems analyzing at least 40 samples per month have no more than 5% of the monthly samples be total coliform-positive and that water systems analyzing fewer than 40 samples per month have no more than one sample be total coliform-positive. Violation of the MCL must be reported to the state no later than the end of the business day on which the water system determines the violation. Every total coliform-positive sample must be analyzed to determine if it contains fecal coliform. Water systems are allowed to analyze for *E. coli* in lieu of fecal coliforms. If fecal coliforms or *E. coli* are detected, the state regulatory agency must be notified by the close of business that day. Water systems are in violation of the total-coliform MCL if (1) any repeat sample (that is triggered by an initial total coliform-positive sample) is positive for fecal coliform or *E. coli*, or (2) there is a fecal coliform or *E. coli* positive original sample followed by a total coliform-positive repeat sample. These violations are considered acute and, therefore, require notification to the state within 24 hours and public notification within 72 hours. State regulatory agencies, however, can grant a variance if the water system can prove that the distribution system biofilm growth is the sole cause of coliform in the distribution system.

2.3.2 Sample Siting Plan

The TCR requires sample siting plans to be approved by the state. The monthly monitoring requirements are based on population served by the water system. For example, water systems serving a population between 4,101 and 4,900 must take five samples per month. Similarly, those serving 4,901 to 5,800 must take six samples, and those serving 5,801 to 6,700 must collect seven samples. Water systems collecting more than one sample per month and having one routine sample total coliform-positive must collect and analyze at least three repeat samples for total coliform. States, such as Texas, may require additional repeat samples (consult state drinking water regulations). One repeat sample must be from the same tap as the original, and the other two must be within five service connections upstream and downstream of the original sample. All repeat samples must be collected within 24 hours of notification of the initial positive result.

Whenever a water system has one or more total coliform-positive repeat samples, the water system must collect sets of three repeat samples until additional samples are total coliform free or there is a violation of the MCL. Failure to comply with the monitoring requirements must be reported to the state. The AF installation then may be required to make a public notification.

2.3.3 Analytical Methodology

Total and fecal coliform, heterotrophic plate count (HPC), and *E. coli* can be analyzed by the following EPA-approved methods:

Analyte	Methodology	Reference
Total Coliforms	Total coliform fermentation technique Total coliform membrane filter technique OMPG-MUG tests	SM 92221,A,B,C* SM 92221,A,B,C* SM 9223*
Fecal Coliforms	Fecal coliform MPN procedure Fecal coliform membrane filter procedure	SM 9221E* SM 9222D*
Heterotrophic Bacteria	Pour plate method	SM 9215B*
E. coli	EC-MUG test Nutrient agar-MUG test MMO-MUG test	*Fed. Reg., 56:5:636; (Jan 8, 1991)* *Fed. Reg., 56:5:636; (Jan 8, 1991)* *Fed. Reg., 57:10:1850; (Jan 15, 1991)*

**Standard Methods for the Examination of Water and Wastewater*, AWWA, 18th Edition, 1993.

2.3.4 Interference by Heterotrophic Bacteria

The TCR requires that repeat samples be collected when there is evidence of interference by heterotrophic bacteria. Interference is indicated by a turbid culture with the absence of gas (using the multiple tube fermentation [MTF] technique), the absence of positive acid reaction (P-A test), or the presence of either confluent growth or a colony number that is "too numerous to count (using the membrane filtration [MF] technique)." If there is evidence of interference, the sample can be declared invalid. The water system is then required to collect another sample, within 24 hours, from the same location and analyze it for total coliforms. The system must continue to sample and reanalyze every 24 hours until a valid result is obtained.

2.3.5 Invalidation of Total Coliform-Positive Samples

Invalidated samples do not count toward compliance. The state may invalidate a sample for one of three reasons:

- The analytical laboratory acknowledges that improper sample analysis caused the positive result.

- The state has substantial grounds to believe that a total coliform-positive result is due to a circumstance or condition that does not reflect distribution system water quality. If this is the case, the determination must be documented in writing, signed, and approved by the state official who made the determination; the document is made available to EPA and the public.

- It is determined that the contamination resulted from a domestic or other nondistribution utility plumbing problem. This determination must be based on collecting one or more repeat samples from the same tap as the original total coliform-positive sample and the result is total coliform-positive, but all repeats at nearby sampling locations are total coliform-negative.

2.3.6 Training

The TCR does not require any specific training; however, some special training may be beneficial.

- **Sample Collection** — The BE sample collectors may undergo additional training for collection of coliform samples. Under the TCR, it is very difficult to invalidate total coliform or fecal coliform-positive samples because of poor sample collection or transportation procedures.

- **Fecal Coliform/*E. coli* Testing** — Laboratory staff must also strictly adhere to the procedures for confirming the presence of coliforms, fecal coliforms, or *E. coli.* and the specific conditions for repeat sampling. A failure to test coliform-positive samples for fecal coliforms or *E. coli* is a procedural failure that requires notification of the state and the public.

- **Maintenance Activities** — The BCE Maintenance Department staff performs work on the distribution system that requires "opening up the system." Maintenance staff should receive regular training on the proper disinfection techniques to use during and after these kinds of maintenance activities.

2.3.7 Quality Assurance (QA)

QA procedures should be implemented by each AF water system in order to comply with the stringent requirements.

- **Preparation of Supplies —** To ensure that positive-coliform samples are valid and are not due to deficient QA procedures, the testing laboratory must conduct QA testing and strictly adhere to the procedures. This is also important because it may be difficult to identify the source of contamination before the deadline for public notification (72 hours after the MCL for total coliform/fecal coliform) is exceeded. Specific examples of testing that need to be done include sterility checks for bacteriological bottles, glassware residue inhibitory tests, regular disinfection of ice chests, and QA protocols for fecal coliform analysis.

- **Coliform Processing Protocol —** Because of the public notification requirements, the procedures for handling total coliform-positive samples must be closely followed. Laboratory staff must strictly adhere to proper protocols for confirming total coliforms and testing for the presence of fecal coliforms or *E. coli.*

  For example, if one fails to test a total coliform-positive sample for the presence of fecal coliform or *E. coli*, this is considered a procedural violation that requires state and public notification. Similarly, if one fails to collect a repeat sample in which interference by heterotrophic plate counts (HPCs) is observed, state and public notification must occur.

2.3.8 Communication

It is critical to establish an effective means of communicating bacteriological results and appropriate sample information from the laboratory to the BE to ensure that samples are processed and interpreted appropriately and in a timely manner.

In addition, a data review system should be developed whereby coliform results are reviewed daily by BE before being entered into a database. A channel of communication between BE and the BCE should be developed to properly handle TCR violations in a timely fashion.

2.4 INFORMATION COLLECTION RULE (ICR)

The ICR was developed in 1993 as an integral part of the negotiated rule-making process, also known as "reg-neg", i.e. regulation by negotiation. This rule became effective during 1995 and is intended to provide real operating data to support the proposed D/DBP Rule and the proposed Enhanced Surface Water Treatment Rule (ESWTR). The ICR contains the following three major components: (1) microbial monitoring, (2) DBP monitoring, and (3) DBP precursor removal studies.

Microbial monitoring is intended to provide data that can be used to:

- Assess pathogen occurrence.
- Understand health risks associated with microbial contamination and the effectiveness of treatment.
- Evaluate the adequacy of the SWTR and the TCR.
- Determine relationships between occurrence and removal of pathogens.
- Evaluate if treatment levels should be determined by source water quality.

DBP monitoring is intended to:

- Determine relationship between raw water quality and DBP formation.
- Determine amount of DBPs in water.
- Refine DBP formation models.
- Define cost-effective monitoring requirements.

The bench- and pilot-scale testing is intended to develop costs for granular activated carbon (GAC) and membrane technology for removing DBP precursors and DBPs. Total organic carbon (TOC) will be used as a surrogate for DBP precursors. Large surface water systems with raw water TOC concentrations in excess of 4.0 mg/L or groundwater systems with treated water TOC in excess of 2.0 mg/L will be required to run bench-scale tests.

2.5 DISINFECTANT/DISINFECTION BY-PRODUCTS (D/DBP) RULE

The proposed D/DBP Rule will be developed in two stages. The first stage set MCLs for total trihalomethanes (THMs) (80 μg/L), five haloacetic acids (HAAs) (60 μg/L), bromate (0.01 mg/L), and chlorite (1.0 mg/L). It is the intent of Stage 2 to reduce the THMs and HAAs by 50%. However, these goals will be reconsidered following completion of ICR monitoring.

SECTION 3

AN ACTION PLAN TO COMPLY WITH THE REQUIREMENTS OF THE TOTAL COLIFORM RULE (TCR)

This section presents an action plan for the BCE and BEE to follow to ensure compliance with the requirements of the TCR. It is divided into two main subsections: (1) bacteriological sampling and (2) corrective actions. The first subsection is a discussion of the various items required in a comprehensive sampling plan. The second subsection discusses corrective actions to be taken by system operating staff to bring the system into compliance. The material presented here draws from material previously published in the following:

- *Principles and Practices of Water Supply Operations*, Volume 3 - Introduction to Water Distribution, AWWA, 1986.
- *Safe Drinking Water Act Management Action Plan for Seymour Johnson AFB*, EA Engineering, Science and Technology, Inc., May 1995.
- Previous WESTON documents.
- *Total Coliforms: A Working Explanation of the Total Coliforms Rule*, SDWA Series, AWWA.

3.1 BACTERIOLOGICAL SAMPLING

The first step in analyzing the bacteriological quality of water in the distribution system is the collection of samples that accurately represent the condition of the water being sampled. This section discusses bacteriological sample collection, preservation, transportation, sampling quality assurance/quality control (QA/QC), and steps that should be taken in the event of a violation.

One of the most common causes of error in water quality analysis is improper sampling. When a sample is tested, the test results show only what is in the sample. If those test results are to be useful, the sample must contain essentially the same constituents as the body of water from which it was taken — i.e., it must be a *representative sample.*

Samples taken within the distribution system may yield water of significantly different quality than samples of finished water taken at the plant. Corrosion, growth of biofilm, and cross-connections are conditions that can significantly deteriorate the quality of treated water before it reaches the customer. The selection of representative sampling points within the distribution system is an important initial step in developing a sampling program that will accurately reflect water quality.

3.1.1 <u>Sample Locations</u>

The number and location of sampling points should be established to ensure compliance with the applicable coliform (bacteria) testing requirements of the state or federal drinking water regulations. The sampling locations must be representative of each different source of water entering the system and of conditions within the system, such as dead ends, loops, storage facilities, and pressure zones. The precise location of sampling points will depend on the configuration of the distribution system.

Once representative sampling locations have been identified on the distribution system map, specific sampling faucets must be selected. These faucets can be located inside a public building, such as a fire station or school building, inside the home of an operator, or inside the homes of other consumers.

Faucets selected for coliform sampling should be on lines connected directly to the main. It is noted that some buildings may have surge tanks or hydropneumatic storage for the purpose of providing adequate supply during high demand periods. Taps connected to storage tanks should not be used. Only cold-water faucets should be used for sample collection because hot water heaters may change the microbial population of the sample. The sampling faucet must not be located too close to a sink bottom. Contaminated water or soil may be present on faucet exteriors, and it is difficult to place a collection bottle beneath these faucets without the interior of the sample bottle neck coming into contact with the outside surface of the faucet. Samples also should not be taken from the following sources:

- Swivel faucets.

- Leaking faucets, which allow water to flow out from around the stem of the valve and down the outside of the faucet, or faucets in which water tends to brim up on the outside of the lip.

- Lines with home water treatment units, including water softeners.

- Homes with separate storage tanks.

- Drinking fountains.

- Faucets with aerators, strainers, or hose attachments. (On nonswivel faucets, these devices can be removed to allow samples to be taken. After removal, care should be taken to avoid sampling loosened material from these attachments. These devices can harbor a bacterial population if they are not cleaned regularly or replaced when cracked.)

- Faucets exhibiting unsteady flow (fluctuations in flow and line pressure can cause biofilm present in the sample faucet and line to break loose).

When a representative sampling point has been selected, it should be marked or described so that it can be easily located for future sample collection.

3.1.2 Sample Collection, Preservation, and Transportation

Once sampling points have been selected, the BEE can begin a regular program of sample collection and testing.

Collecting coliform samples involves a few simple, carefully performed steps. The key to accurate sampling is preventing contamination by allowing nothing except the sample water to enter the bottle or touch the bottle cap or neck. Adherence to the following steps will minimize the occurrence of inaccurate sampling:

1. Use only the bottles provided by the laboratory specifically designated for coliform sampling. If sterilized bottles are not available from the testing laboratory, use wide-mouth glass or heat-resistant plastic bottles with screw caps that have been sterilized in an autoclave prior to use.

2. *Do not rinse the bottles.* There is a chemical in the bottles that destroys any residual chlorine in the water. The residual chlorine would otherwise kill any bacteria in the sample, yielding an incorrect test result.

3. Keep sample bottles unopened until the moment of filling. The bottles are sterile.

4. Make sure the faucet has no aerator and no swivel. Outside faucets should be prepared by squirting with a concentrated chlorine solution and then flushing. Flaming the outside of the faucet is not recommended.

5. Flush the faucet for 10 to 15 minutes to clear any stagnant water from the service line.

6. Hold the bottle near the base; do not handle the stopper or cap and neck of the bottle.

7. When flushing is complete, without changing the flow, gently fill the bottle *without rinsing*. Leave an air space at the top. Changing the flow can dislodge particles in the pipe, valve, or faucet.

8. Replace the cap or stopper immediately.

9. Using a separate sample, test for free chlorine residual and record the result.

10. Label the bottle, be sure to include the date and time the sample was taken, and package it for delivery to the laboratory.

The following additional items should be considered when sampling:

- Do not place sample bottle or cap on the ground or in a pocket.

- Do not let splashing drops of water from the ground or sink enter either the bottle or cap.

- Do not touch the inside of the bottle or cap.

The number of coliform bacteria in a sample begins to change immediately after the sample is collected. These changes are slowed somewhat by the chemical supplied in the sample bottle, which neutralizes any chlorine residual. These changes can be further slowed by keeping the bottle cool until the time of testing. However, bacteriological testing should always be performed as soon as possible after the sample is collected—within 24 hours as a maximum.

Samples should be stored and shipped in insulated containers or insulated sample bottles. Bottle caps should be tight enough to prevent leakage, and bottles should be packed in a sturdy container with enough cushioning material to prevent breakage. If the samples are to be analyzed by a laboratory in another city, a method of shipment must be found that will ensure that the samples arrive at the laboratory within 24 hours (preferably less) of the time the sample was taken.

3.1.3 Analytical Procedures

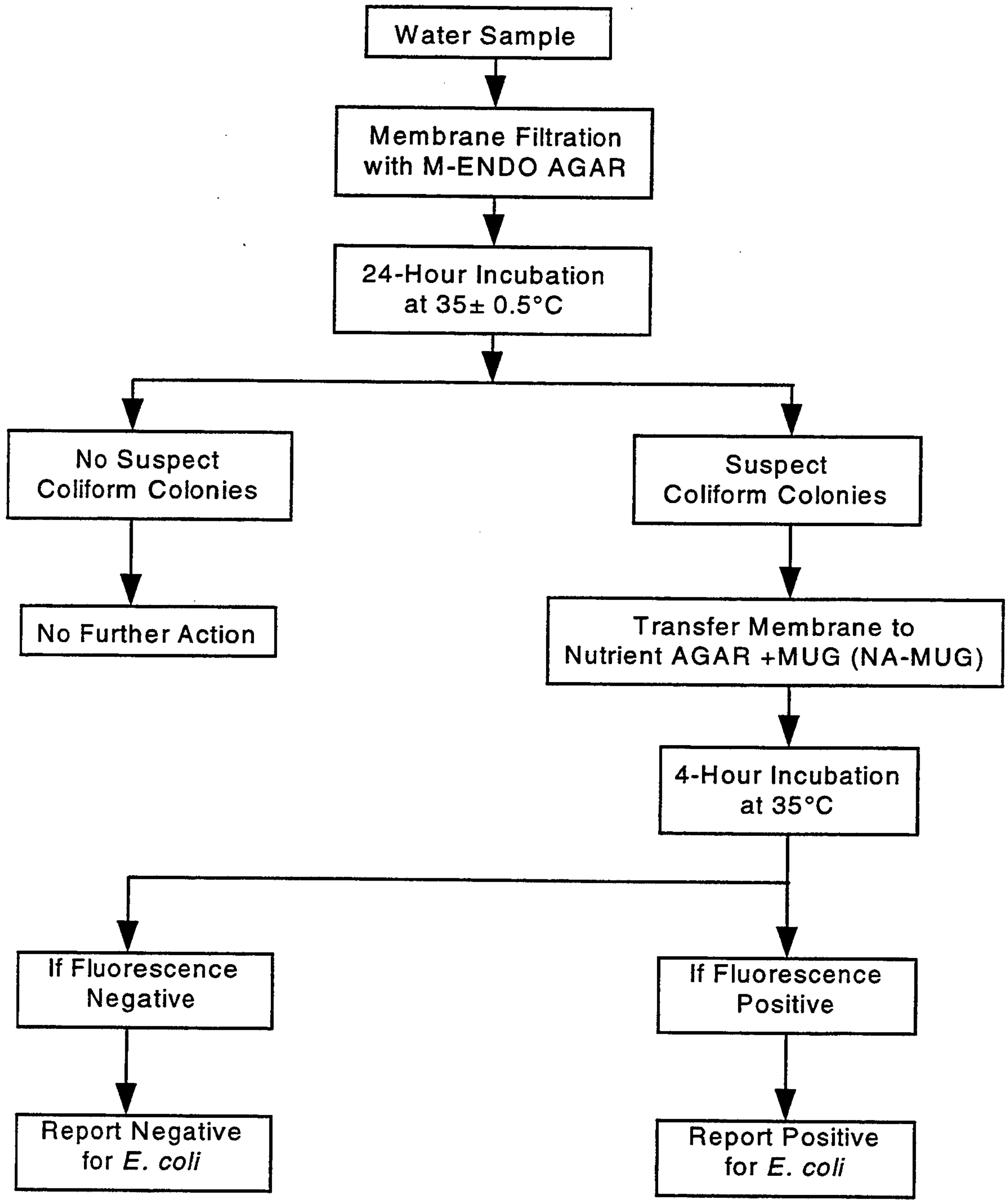
Accepted analytical procedures for coliform analyses were presented previously. A sample flow chart describing the analytical procedure for coliform detection is shown in Figure 3-1.

3.1.4 Sampling Plan Quality Assurance/Quality Control (QA/QC)

A good QA/QC Plan is very important to obtain valid results. A detailed QA/QC Plan presented in the *Safe Drinking Water Act Management Action Plan for Seymour Johnson AFB,* EA Engineering, Science, and Technology, Inc. (1995) is reproduced in this subsection.

> The importance of following good QA/QC procedures during sample collection cannot be overemphasized. Practicing appropriate QA/QC procedures will ensure that the data generated from the sampling exercise are meaningful, complete, accurate, admissible as legal evidence (if necessary), representative, precise, and comparable.
>
> Sampling QA/QC begins with a well written sampling protocol that includes a detailed discussion of the following issues:

ANALYTICAL PROCEDURE
FOR COLIFORM DETECTION



Source: *Total Coliform Rule Action Plan*, East Bay Municipal Utility District, Oakland, California.

FIGURE 3-1

- Sampling locations
- Sample types
- Number of samples
- Sample volume
- Equipment to be used in sampling (if any)
- Preparation of sample containers
- Blanks (field, trip and equipment)
- Duplicates and triplicates
- Replicates
- Chain-of-custody forms
- Sample frequency
- Duration of sampling
- Sample collection methods and holding times
- Sample containers
- Type and amount of preservative to be used
- Spiked samples
- Sample shipping

Where appropriate, the sampling plan should include maps and figures to indicate sampling locations.

Sample collection should be conducted using sampling equipment and sample containers that have been decontaminated according to protocols that are appropriate for coliform analysis. Care should be taken to ensure that the water samples do not pick up any contamination from the addition of preservatives, or from handling, storage, or shipping procedures. All of this information is essential for proper sample handling.

Sample identification involves labeling the sample container with appropriate information. The importance of sample identification cannot be overstated. Improperly or inadequately labeled samples are of little value and may sometimes lead to erroneous reporting and permit violations. Improperly identified samples lead to questions with regard to location, sampling station, date sampled, and sampler.

At a minimum, the sample container should be labeled with the following information:

- Date collected
- Time collected
- Collected by
- Preservatives used
- Project ID
- Sample description
- Station/Location
- Sample code number or ID

Pre-printed, pressure-sensitive labels containing space for each of these items are available from many laboratories. Blank labels may be used as long as they contain all of the required information. Alternatively, indelible markers may be used to record the required information directly onto plastic containers. Failure to provide the requested information may result in wasted time, wasted resources, and regulatory penalties if it is necessary to discard samples.

A chain of custody is an established legal mechanism for tracing custody from the time of collection through reporting of results. The chain is initiated by the sampling agent who prepares a chain-of-custody (COC) form. Once completed, the COC form must physically accompany the

sample containers through shipping and laboratory testing. When samples are transferred from one person to another (for example from the sampling agent to laboratory personnel) both parties must sign the COC form to indicate sample transfer.

QA/QC related to sample shipping includes appropriate attention to details such as the following:

- Use of appropriate shipping containers.
- Use of wet or dry ice, as recommended.
- Use of appropriate "filler materials" to ensure that the sample containers are not damaged in transit.
- Inclusion of the COC form (in a waterproof pouch).
- Sealing the shipping containers appropriately, including seals to indicate tampering with the containers, if required.
- Using the appropriate shipping agency (such as an overnight delivery service) to ensure that samples arrive at the laboratory promptly. Particular attention must be paid to samples scheduled for delivery on Saturday.
- Recognition of holding times for all parameters.

Maintaining good field records is an integral part of sampling QA/QC. Sampling field records should be maintained in a bound notebook and should detail information such as the following:

- Any change in odor or visual appearance of the sample.
- Any change in physical appearance of the sampling faucet.
- Alterations in sampling protocol, if any.
- Other observations that may be relevant.

All field records should be signed and dated by the person conducting the sampling.

Each instrument used during field sampling (e.g., a pH meter) should be calibrated according to the manufacturer's instructions.

3.1.5 Violations of the TCR

Water systems can be in violation of the monthly MCL for total coliforms in two ways:

1. If the number of total coliform-positive samples exceeds 5.0% of the monthly samples when 40 or more samples are analyzed or if more than one sample is positive when less than 40 samples are analyzed (a nonacute Tier 1 public notice violation)

2. If there is a combination of:

   (a) A coliform-positive original sample that is also positive for fecal coliform (or *Escherichia coli [E. coli]*) followed by a positive coliform repeat sample, or

   (b) A coliform-positive original sample followed by a coliform-positive repeat sample that is also positive for fecal coliform or *E. coli* (an acute Tier 1 public notice violation).

If total coliforms are detected in any sample, the TCR requires that several measures be taken immediately.

1. The coliform-positive sample must be analyzed to determine whether fecal coliforms or *E. coli* are present. The state must be notified within 24 hours if a violation occurs.

2. Repeat samples must be collected within 24 hours of being notified of a positive coliform sample by the laboratory. The number of repeat samples required is three. At least one of the repeat samples must be taken from the same location as the original sample. The others may be taken at any one of the next five service connections above or below the original sampling location.

3. If coliforms are detected in any repeat sample, another set of repeat samples must be collected from the same location, unless the MCL has already been violated and the system has notified the state and the state has modified the sampling scheme.

4. If coliforms are detected in any original or repeat sample and the sample is not invalidated by the state, a minimum of five routine samples must be collected the next month it is in operation.

5. If any original or repeat sample is coliform-positive, that result counts as a positive result in compliance calculations, and the system has to determine whether the coliforms in the sample(s) include fecal coliforms. Presence of fecal coliforms or *E. coli* in a repeat sample constitutes an acute violation.

The state may invalidate a sample if the system can demonstrate that the contamination is limited to the service connection and that the distribution system is unaffected. Also, a sample may be

declared invalid if the laboratory agrees that it made an error or if the state and EPA agree that there are mitigating circumstances based on a written report by the state. Figure 3-2 is a flow chart that identifies the specific conditions under which the BEE must order collection of repeat samples and when a violation has occurred.

3.1.6 Public Notification

The TCR requires public notification for a variety of occurrences. These occurrences are listed in Table 3-1.

Table 3-1

Events Requiring Mandatory Public Notification
Under Total Coliform Rule

- Exceeding MCL of 5% positive coliform samples/month (for systems analyzing ≥ 40 samples/month)
- Exceeding MCL of one positive coliform sample/month (for systems analyzing < 40 samples/month)
- Occurrence of a fecal coliform/*E. coli* and a total coliform in consecutive samples from the same site (this is considered an acute violation of the MCL for total coliforms)
- Failure to provide sample siting plan
- Failure to perform sanitary survey (for systems analyzing < 5 samples/month)
- Failure to run routine samples
- Failure to collect repeat samples
- Failure to test positive total coliform sample for fecal coliforms/*E. coli*

Whenever the laboratory reports a total coliform-positive result in a sample from a primary sample station, repeat samples from that primary station and an upstream and a downstream station must be collected within 24 hours. Between the time that the initial total coliform-positive results are reported and the repeat samples are required to be collected, the BEE must act to immediately initiate corrective action based on a corrective action plan. If the corrective action is not successful, then the state and the public should be notified, based on the schedule shown in Figure 3-3.

Public notification language for each acute violation notification scenario should be drafted. This language should receive thorough internal review and should also be submitted to the state for preapproval.

In addition to violations of the coliform MCL, the water system is in violation of the TCR when it fails to perform any of the following items:

TCR-REQUIRED PROCEDURE FOR MONITORING AND NOTIFICATION

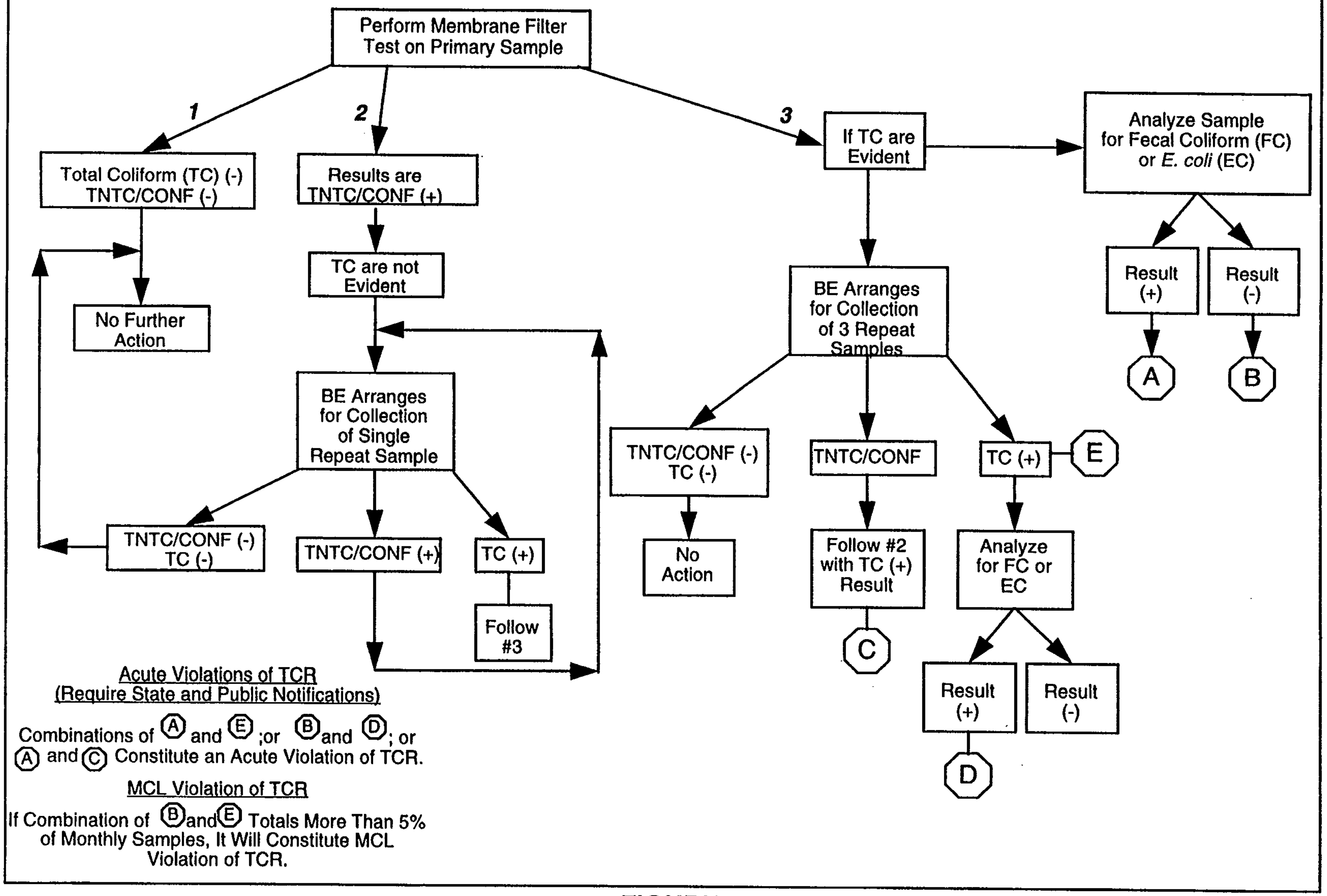


FIGURE 3-2

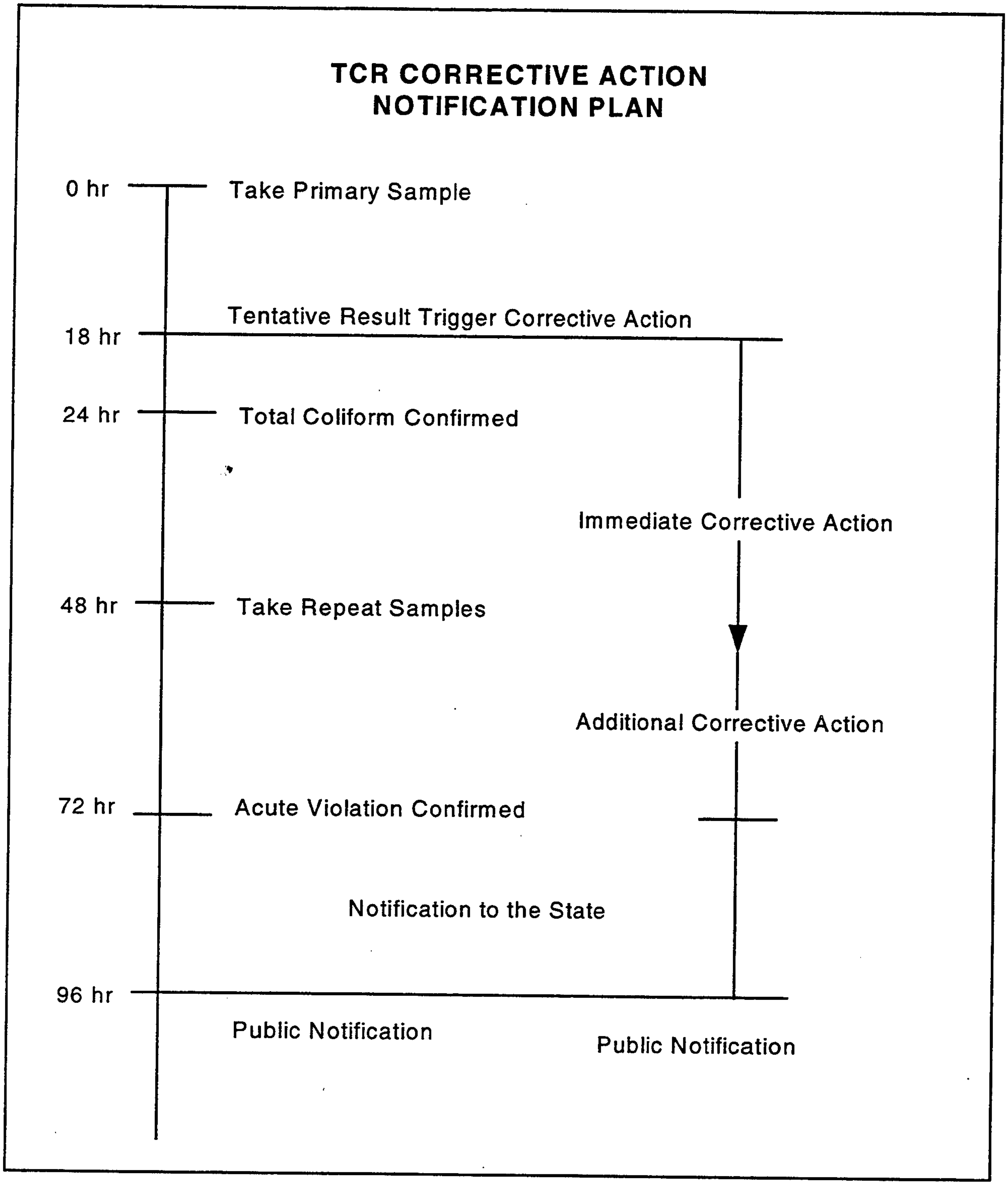

TCR CORRECTIVE ACTION
NOTIFICATION PLAN
0 hr
Take Primary Sample
Tentative Result Trigger Corrective Action
18 hr
24 hr
Total Coliform Confirmed
Immediate Corrective Action
48 hr
Take Repeat Samples
Additional Corrective Action
72 hr
Acute Violation Confirmed
Notification to the State
96 hr
Public Notification
Public Notification

FIGURE 3-3

- Collect repeat samples.
- Test a coliform-positive sample for fecal coliform or *E. coli.*
- Perform a sanitary survey and develop a sampling plan.

3.2 CORRECTIVE ACTIONS

Each AFB water system should develop a corrective action plan to deal with violations of TCR. Corrective actions for acute violations should be started immediately as soon as the initial total coliform-positive results are reported. These actions should be based on the prepared corrective action plan.

This section presents general information on bacterial growth and biofilm formation in the distribution water mains and describes the corrective actions that personnel should take upon notification that a coliform violation has occurred.

3.2.1 Biofilm Growth

It is recognized that microbial cells can attach to distribution system pipe walls and can develop biofilms that can harbor additional bacteria. Though these coliforms are not generally of fecal origin, they can cause violations of the total coliform rule. States can grant a variance if the water system can prove that the biofilm is the sole cause of coliform in the distribution system.

Heterotrophic bacteria measured by the HPC are the most common bacteria in the biofilm. In heterotrophic bacteria, a closely related group of microorganisms, called coliform, is found. Coliform organisms are used as indicators of pathogenic organisms in the water supply. The indicator systems used are:

- Total coliform.
- Fecal coliform.
- *Escherichia coli* (*E. coli*).

The total coliform, in general, consists of the following bacteria groups:

- *Klebsiella* (source: mostly environment, animals/humans).
- *Escherichia* (source: humans/animals).
- *Enterobacter* (source: mostly environment, humans).
- *Citrobacter* (source: environment).

Fecal coliforms consist of:

- *Escherichia coli.*
- *Klebsiella.*

Only a small percent of *Klebsiella* is of fecal origin. Biofilm in the distribution system is a common phenomenon consisting of *Enterobacter* and *Klebsiella* promoted by nutrients, warmer temperatures, and stagnation in the distribution system. Therefore, high potential for bacterial regrowth in the distribution system may occur under the following situations:

- Unlined old cast-iron main with tuberculations
- Dead ends
- During summer months
- High assimable organic carbon (AOC) in finished water
- Absence of residual disinfection

Organic carbon is usually a growth limiting nutrient for coliform bacteria. Organic carbon in water is measured as TOC; as dissolved organic carbon (DOC), which is a soluble fraction of TOC; and as AOC, which is the fraction of DOC that bacteria can use for growth. Often AOC comprises 0.1 to 9% of TOC (Vander Kooij et al., 1982). Water systems should try to limit AOC levels to less than 100 µg/L to reduce coliform levels.

Growth of biofilm in the distribution system causes increased frequency of coliform-positive samples, loss of disinfection residuals, increased turbidity, taste, odor, and corrosion. If biofilm in the distribution system is the cause of the presence of total coliform in the distribution system, a variance from TCR should be obtained or biofilm should be eliminated from the distribution system. Table 3-2 shows criteria for obtaining a variance to TCR.

3.2.2 <u>Detection of Biofilm Occurrence</u>

In case of consistent coliform occurrences in the distribution system, it is necessary to confirm whether biofilm growth in the distribution system is the cause of the presence of coliform. The following steps can be followed to make this determination:

1. Check treatment and disinfection deficiencies by monitoring coliform bacteria from each filter effluent for coliform bacteria and spikes of turbidity. Check distribution system inlet water for low disinfectant residual and inadequate "CT" values.

2. Conduct a thorough sanitary survey to detect treatment deficiencies and distribution system problems (cross-connections, main breaks, backflows).

3. Monitor disinfectant residuals at inlet locations and throughout the distribution systems. Coliform and HPC can grow under low disinfectant residuals. At 0.2 mg/L level of free chlorine residual, HPC levels are expected at less that 500 colony-forming units per milliliter (cfu/mL) in 98% of the samples (McCabe et al., 1970)

Table 3-2

Criteria for Obtaining a Variance to the Total Coliform Rule

The following criteria serve as a guidance for states in identifying systems that could operate under a variance without posing an unreasonable risk to health:

1. Over the past 30 days, water entering the distribution is shown to:
   a) Be free from fecal coliform or *E. coli* based on at least daily sampling.
   b) Contain less than 1 total coliform/100 mL of influent water in at least 95% of all samples based on at least daily sampling.
   c) Comply with the total turbidity requirements under the Surface Water Treatment Rule.
   d) Contain a continuous disinfection residual of at least 0.2 mg/L.
2. The system has had no waterborne disease outbreak while operating in its present configuration.
3. The system maintains biweekly contact with the state and local health departments to assess illness possibly attributable to microbial occurrence in the public drinking water system.
4. The system has evaluated, on a monthly basis, at least the number of samples specified in the Total Coliform Rule and has not had an *E. coli*-positive compliance sample within the last 6 months, unless the system demonstrates to the state that the occurrence is not due to contamination entering the distribution system.
5. The system has undergone a sanitary survey conducted by a party approved by the state within the past 12 months.
6. The system has a cross-connection control program acceptable to the state and performs an audit of the effectiveness program.
7. The system agrees to submit a biofilm control plan to the state within 12 months of the granting of the first request for a variance.
8. The system monitors general distribution system bacterial quality by conducting heterotrophic bacteria plate counts on at least a weekly basis at a minimum of 10% of the number of total coliform sites specified for that system size in the Total Coliform Rule (preferably using R_2A medium and the procedure outlined in *Standard Methods* [AWWA, 1989]).
9. The system conducts daily monitoring at distribution system sites approved by the state and maintains a detectable disinfectant residual at a minimum of 95% of those points and a heterotrophic plate count of less than 500 colonies/mL at sites measured without a disinfectant residual.

Source: U.S. EPA, 1991. Drinking Water, National Primary Drinking Water Regulations, Total Coliforms. *Federal Register* 56(10): 1556-1557.

4. Monitor the following characteristics of biofilm growth in the distribution systems:

   - Seasonality — Biofilm growth generally starts in March-April, peaks in July-August, and subsides in mid-October.

   - Density — High density of coliform occurrence may associate with high AOC levels in water.

   - Diversity — *Klebsiella* and *Enterobacter* are predominant in biofilm. Growth of heterotrophic bacteria usually occurs before coliforms. HPC level trends may be a guidance to determine presence of biofilm.

   - Coliform bacteria — May be present in biofilm in distribution system even in presence of high residual disinfectant.

   - Nutrient Levels — Nutrient levels play an important role in the growth of biofilm. Decline in AOC levels is consistent with bacterial growth in the distribution system.

   - Hydrodynamics — Sudden change in hydrodynamics in the distribution system (fire flow, flushing operation, high demand day) can detach biofilms from pipe walls and result in increased coliform levels.

   - Stagnation of Water — Decreased flow and velocity in the distribution pipe (dead ends, low usage, storage tank) increases coliform levels due to stagnation of water and loss of disinfectant residuals.

Once biofilm growth in the distribution system is identified, a corrective action plan for biofilm control should be developed.

3.2.3 Corrective Action Plan

A corrective action plan should have all components to control biofilm growth in the distribution system, and each component should have corrective actions that require implementation in various time frames: immediate (within days), short-term (within 1 year), and long term (1 to 5 years). Table 3-3 shows a summary of such an action plan.

Table 3-3

Summary of Corrective Action Plan to Control Biofilm Growth

Component	Action Plan: Immediate	Action Plan: Short-Term	Action Plan: Long-Term
a. Distribution System Maintenance	Once coliform is detected: – Isolate the affected water mains and flush. – Increase disinfectant residual levels	Develop and implement the following: – A regular flushing program. – A valve operation and exercise program. – A cross-connection control program. – A dead end management program. – A program for disinfection of mains after repair or replacement.	Develop and implement the following: – A pipeline rehabilitation and replacement program – A database of historical maintenance records of water mains – Storage tank inspection and rehabilitation
b. Maintenance of Disinfectant Residual	– Increase dosage of disinfectant. – If necessary, install new booster disinfecting dosing stations.	– Review possible alternative disinfectants usage – Identify stagnant areas of distribution mains by using computer model – Review or conduct a "CT" study, as required by SWTR.	
c. Treatment	– Measure disinfectant residual of treatment plant effluent. – Monitor AOC and turbidity in filter effluent.	Develop and implement a corrosion control plan – Adjust pH. – Use chemical corrosion inhibitors.	If AOC in treated water is high, develop a plan for change in treatment by addition of – Activated carbon filters. – Mixed carbon/sand filters. – Biologically active filters.

3.2.4 Immediate Actions

Actions are taken by the BCE and BEE immediately upon notification of a coliform violation. The actions described in this section are:

- Boosting chlorine dose.
- Sampling of inlet to the distribution system.
- Flushing and disinfection.
- Correcting system deficiencies.
- Monitoring nutrient levels and turbidity in the plant effluent.

These actions are to be carried out in conjunction with the repeat sampling described in the previous section.

The first action response to the presence of coliforms should be to measure chlorine residuals and, if necessary, to increase chlorine feed at the entrance of the distribution system to make sure that adequate residual chlorine is available in all parts of the distribution system.

The inlet to the distribution supply line should be sampled for AOC and coliform to determine if the coliform being introduced to the system and high levels of AOC (more than 100 μg/L) are from purchased water. If sampling indicates that the purchased water is the source of coliform or high levels of AOC, the BEE must notify the wholesale purveyor of the condition. In addition, chlorine addition should be continued until the wholesale purveyor has determined the cause of the coliform problem, has taken steps to correct it, and has corrected the problem.

If sampling indicates that the problem is a local problem, the water distribution system in the area of the coliform violation should be flushed. This procedure involves isolating the mains to be flushed by closing appropriate valves and opening a fire hydrant to cause water to flow through the isolated pipe section. Water should flow at a velocity of at least 2.5 feet per second to obtain proper flushing action. The following flow rates are required to produce a velocity of 2.5 in each of the mains listed.

Diameter (inch)	Flow Required (gpm)	Volume in a 100 ft Section of Pipe (gal)
4	100	66
6	200	147
8	400	261
10	600	408
12	900	587
16	1,600	1,044

The line should be flushed until the water runs clear or 10 to 20 "pipe volumes" of water have been removed from the main.

It may be necessary to add chlorine to the isolated main to kill the bacteria. This should be followed by flushing to remove the chlorinated water and dislodged biofilm from the pipe line.

The BCE and BEE also should conduct a quick inspection of the system to insure that the system is being operated correctly and to address any deficiencies found. For example, a new water line or service tap may have been added to the system without proper disinfection procedures having been followed. Distribution workers may have flushed a portion of the system and stirred up sediment and biofilm that has migrated to the sampling point. Pressure records may indicate that a backflow event may have occurred. These are examples of system deficiencies that could result in coliform contamination of the system and should be corrected.

In cases where AFB water systems have treatment plants, effluent from each filter should be monitored for turbidity and turbidity spike.

3.2.5 Short-Term Programs

Short-term programs (0 to 1 year) should be implemented by the BCE and BEE following review of the immediate action plan for coliform problems and after determining a program to address the coliform control problem of the system to maximize water quality. The short-term programs proposed and described in this section are as follows:

- Routine system flushing and valve exercising.
- Disinfection of mains after repair/replacement.
- Change disinfectants.
- Dead ends and stagnant area management.
- Backflow prevention and cross-connection control.
- "CT" value evaluations.
- Corrosion control.

Flushing Program

AFB water systems should flush distribution mains for biofilm control, taste and odor control, corrosion control, low residual chlorines, and control of turbidity and color. Flushing is important to maintain good water quality.

A regular flushing of the distribution system is an effective preventive procedure for reduction of biofilm growth. A valve exercising program is necessary to keep all valves in the system operational. This will help to isolate water mains for flushing. This should be routinely conducted to keep all valves operable.

Sand, corrosion products, and other solids have a tendency to settle in the pipeline, especially in dead ends or stagnant areas of low water consumption. These deposits can reduce the carrying capacity of the pipe and are often a source of color, odor, and taste problems as well as coliform problems associated with slime growths. Flushing at high velocities, at least twice a year in problem areas, will normally remove most of the settled substances and discolored or stale water.

Flushing is accomplished by fully opening a hydrant located near the problem area. The hydrant should be kept open as long as it takes to flush the sediment out. Only through on-the-job experience will an operator be able to tell how often or how long certain areas should be flushed. Operators must, however, respond to customer complaints of dirty water and flush problem areas. If flushing is made a part of routine scheduled maintenance and if it is done properly, it will minimize biofilm formation (i.e., reduce coliforms) as well as eliminate many customer complaints, meter repairs, and service-line blockages. Flushing also provides a good opportunity for operators to perform scheduled hydrant inspections.

The following points should be considered when developing a program or performing flushing:

- A map of the system and past experience should be used to plan the flushing schedule, paying particular attention to potential problem areas and areas where there have been a high incidence of customer complaints. The flushing procedures should be performed first in the distribution inlet area and proceed to the ends of the distribution system.

- Flushing the system late at night will achieve greater flows through the line and cause fewer customer complaints. If possible, announcements should be made to base personnel to explain the flushing schedule in advance of the work, and to alert customers that there may be a temporary condition of discolored water. Customers should be advised that, after flushing is completed, they should not use water from their service until they have run enough water to thoroughly flush their service lines.

- The work of flushing crews should be coordinated to avoid flushing too many hydrants at once, which could cause a negative pressure, thus increasing the chances of backflow through any existing cross-connections. Before flushing, the area in which the flushed water will drain should be inspected to ensure that the water will not flow into basements, excavations, or buildings.

- Higher pumping pressures and/or shutting off branch lines will increase the effectiveness of the operation. A pipe flow of at least double the velocity normally

recommended (2.5 feet per second [fps] or 220 gpm in a 6-inch main [0.76 m/s or 830 L/min in a 150-mm main]) is usually required for effective flushing.

- The hydrants must be opened fully—the hydrant valve is not a throttling valve. The hydrant valves should be opened and closed slowly to prevent water hammer. A diffuser, screen, length of fire hose, or other means of breaking up the force of the water stream is recommended, especially in unpaved areas.

- Flowing hydrants should not be left unattended, and flushing should be stopped if the water is damaging a roadway or parkway. If the street or parkway is accidentally damaged, it should be marked with a lighted barricade and the location recorded so that the damage can be repaired as soon as possible. Flushing should be continued no longer than necessary to remove sediment and to ensure that the hydrant is operating properly.

- When flushing of a hydrant is completed, the hydrant should be checked to ensure that it drains when it is shut off. This checking can be done by feeling by hand for a slight vacuum at the open nozzle, by listening for air being drawn in with the outlet cap on loosely, or by running a weight on a line down inside the hydrant. Plugged hydrants must be pumped out if freezing is a possibility. Nozzle caps must be tightened so they cannot be removed by unauthorized persons.

- Records should be kept for each hydrant flushed, length of time flushed, time required to obtain clean water, water condition at the start and end of flushing, and other special notations. Defective hydrants should also be noted, flagged as inoperative, and reported for immediate repair.

Disinfection of Mains

Operating procedures used by the BCE should maximize the "biological" integrity of the distribution system. In addition to the items already discussed, proper procedures should be followed during main construction and replacement to ensure the cleanliness of the water system. The following section describes procedures that must be followed whenever a pipe is repaired, a service connection made, or new lines constructed.

Any new or repaired water main must be thoroughly cleaned (flushed), disinfected, and tested for bacteriological quality before it can be put into service.

Mains should be flushed prior to disinfection in order to remove any foreign material that may interfere with disinfection or reduce water quality.

Flushing should be done through a convenient hydrant or other blowoff. It should be done at a velocity of 2.5 fps (0.8 m/s) to obtain proper flushing action.

Chlorine is the only chemical used as a disinfectant for pipelines. Calcium hypochlorite and sodium hypochlorite solution are the forms in which it is usually used.

The chlorine requirement depends on local and state requirements, the degree of contamination, contact time allowed, and the pH of the water. However, the rate of application should result in a uniform concentration of at least 25 mg/L at the end of the section being treated. Under certain conditions, higher chlorine dosages may be required.

The average retention period should be 24 hours. If unfavorable or unsanitary conditions exist, the period may have to be extended to 48 or 72 hours. If shorter retention periods must be used, the chlorine concentration should be increased to 50 or 100 mg/L. Never discharge highly chlorinated water without checking with local or state regulatory agencies. The efficiency of disinfection must be checked through bacteriological tests before the line is placed in service.

Alternative Disinfectants

Some studies have shown that changing disinfectants can have a positive effect on reducing biofilm growth. LeChevallier et al. (1990) reported a 3-log die off in biofilms treated for 2 weeks with 4 mg/L of monochloramine. These same biofilms showed no significant changes when treated with 4 mg/L of free chlorine for 2 weeks. Accumulation of corrosion products on iron pipes was found to interfere with free chlorine disinfection. A study for alternative disinfectants should be conducted before changing the disinfectant.

Dead Ends Management

Residence time is an important factor in managing distribution system water quality. Distribution water quality computer models are excellent tools to identify areas of high residence time under various modes of system operation. High residence time and variation of residence time at various points can be identified and plotted.

Dead end pipes or areas with low demand are locations where water will stagnate and biofilm problems arise as well as septic conditions and taste and odor problems. The dead ends should be "looped" or connected to the extent feasible to promote movement of water through these areas. Other dead ends should be flushed regularly. A computer model can be used to identify stagnant distribution areas. Operation of pumps can be changed to improve flow in these areas.

Dead ends in a distribution system should be clearly marked on the distribution system maps or in the database. Dead ends should have blow-off valves. Good water quality near dead ends should be maintained by implementing a regular flushing program. As a minimum, blow-off valves should be opened and dead ends should be flushed once per year at the beginning of the peak demand season. In developing a dead end management program, water systems should also try to reduce the number of dead ends by forming loops in the distribution system.

Cross-Connection Control Program

Backflow and cross-connection also can be a source of coliform contamination. However, if caused by backflow and cross-connection, the contamination is usually much more wide spread and it is a major breach of system integrity. The BCE and BEE should develop a backflow prevention and cross-connection control program.

CT — Value Evaluation

SWTR requires evaluation of "CT" values in the distribution system. A "CT" value study should be conducted to make sure that the requirements of 3-log reduction of *Giardia* and 4-log reduction of viruses are met.

Corrosion Control

Limiting corrosion in distribution mains limits biofilm growth on the wall of mains. The Lead and Copper Rule also requires optimizing of corrosion control of the distribution system. The following methods are generally used in the treatment of water to make it less corrosive:

- Increase pH.
- Use corrosion inhibitors that will form a barrier on the pipe surface to protect the pipe from the water.

AFB water systems that developed a corrosion control program as part of the Lead and Copper Rule may not require any additional corrosion measures. These corrosion control measures showed the effectiveness of free chlorine disinfection of biofilms (LeChevallier et al., 1990).

3.2.6 Long-Term Programs

Rehabilitation of Water Mains

Surface tuberculation forms as a result of bacterial corrosion and deposition on the wall of unlined cast-iron water mains. Growth of these tubercles not only reduces the cross-sectional area, and consequently the water-carrying capacity of the distribution system, but also provides greater surface area for bacterial attachment and growth. This bacterial growth in the tubercle exerts increased chlorine demand thereby reducing the chlorine residual in the distribution system. Thus, unlined cast-iron mains, particularly with low water velocity (dead ends), will have high potential for bacterial growth, low residual chlorine, discolored water, and taste and odor problems.

AFB water distribution systems largely consist of old, unlined cast-iron water pipes. These pipes show tuberculation on inside walls due to chemical and bacteriological corrosion. Biofilm growths are usually found in these tuberculated pipes. Cleaning and lining of these pipes will

prevent growth of biofilm and also will increase hydraulic capacity of these water mains. AFB water systems having old, unlined cast-iron mains should develop a program for cleaning and lining of these mains.

Removal of encrustation may not be a permanent solution to coliform or dirty water problems. Without lining the pipe or treating the corrosivity of the water, the problem may reoccur rapidly. However, experience has shown that in many cases leaving just a few mils of iron oxide on the smooth interior of the pipe wall delays the occurrence of red water and the regrowth of encrustation and their associated coliforms.

Thorough planning should precede actual cleaning. The section of main or system to be cleaned should be mapped. The order of work, source of water, entry and exit points, and disposal of the flushed water should all be determined. The vehicles to be used, size of crew, and equipment and materials that will be required can then be listed and made available.

Before cleaning, valves and hydrants should be checked to ensure they are operable. Customers should be notified concerning the date and time the system will be out of service, and temporary water service should be arranged for any customers who must have water for medical reasons.

Other utilities and agencies that will be affected by the planned operation should be notified, including police and fire departments. Regulatory agencies should be consulted concerning any special requirements, and any necessary safety procedures should be planned.

Before flushing or cleaning any main, provision should be made to control pressure surges. A sudden stopping of flowing water can occur if a line valve is operated rapidly or if a pig or swab suddenly slows or stops moving. Such surges can raise system pressure 20 to 60 psi (450 to 1350 kPa) for each foot per second (meter per second) of velocity change. These surges can destroy water mains and appurtenances.

In the air purging process, air mixed with water is used to clean small mains up to 4 inches (100 mm) in diameter. Before performing the procedure, all services must be shut off. Air from a compressor is then forced into the upstream end of a main after the blow-off is opened at the downstream end. Spurts of the air-water mixture will remove all but the toughest scale.

Use of swabs and pigs entails the introduction of a device into the water main that will scrap the sides of the main and remove the accumulated debris. These devices are available in a variety of shapes, sizes, and roughness for use under a wide variety of pipe conditions. The pig or swab is introduced to the system at a hydrant and water pressure is used to move the pig through the pipe to a point where it can be retrieved. This is usually where the dirty water from the main is also removed.

The following is a general procedure for cleaning a line with pigs:

1. Be sure initial procedures have been completed.

2. Install the equipment necessary at entry and exit points for launching and retrieving of pigs. In many cases, it will be necessary to cut into the main to install the equipment.

3. Isolate the water main to be cleaned; be sure all gate valves are open.

4. Make provisions to control surges.

5. Open upstream water supply to launch pig.

6. Time passage of the pig in order to properly gauge the valve setting required to achieve the desired speed.

7. Control speed of pig with downstream hydrant or blow-off valve. Typical speeds are 1 to 5 fps (0.3 to 1.5 m/s). If pigs travel too fast, they remove less material and wear out more rapidly.

8. Take care to avoid sudden changes in speed or a stoppage in pig movement, which will cause destructive surges in water pressure.

9. Run final flush until water turns clear.

After cleaning a water main with swabs or pigs, flush the main until the water runs clear. Test the quality of the water in the main, and chlorinate, if necessary, before returning the line to service. Check that all valves are in proper operating position and that all services have been reactivated.

A flow test should be conducted on the main before and after swabbing or pigging is performed. After cleaning has been carried out, another test should be made to determine if further cleaning is necessary.

Cleaning can restore the interior surface of pipe to a condition close to that of a newly laid main. However, experience has shown that cleaning mains without lining them is only a temporary solution. Cleaning does not remove the causes of pipe deterioration. Tuberculation happens much faster after cleaning, and the flow coefficient declines back to its previous level. For this reason, cleaning alone is an expensive and relatively inefficient way to maintain carrying capacity.

After cleaning, pipe can be lined in place with a thin layer of cement mortar. This not only prevents recurrence of interior surface deterioration, but it also prevents red water and stops leakage. Cleaning and lining the pipe will result in improved water quality, volume, and pressure to the customer. It will also decrease pumping, operations, repair, and replacement costs to the community.

Another method of lining existing water mains that are prone to tuberculation is slip lining with a high-density polyethylene (HDPE) pipe. Plastic pipe is lightweight and flexible and can be either pulled or pushed into the existing main from access points cut into the system. Valves, tees, and services must be recut, the same as with the cement-mortar lining.

Storage Tank Rehabilitation

Distribution system storage tanks also can be a source of coliform contamination. All tanks should be inspected to ensure the "biological" integrity of the tank as well as its structural integrity and the condition of its coating. The "biological" integrity of a tank requires that hatches, air vents, overflows, and all other openings are screened and designed to eliminate the entrance of birds, animals, insects, and stormwater runoff. Also, all personnel should be disinfected with a bleach solution before entering the tank.

Storage tanks also can be the source of coliforms due to long detention times, especially during the warmer months. Steps should be taken to ensure that water remains in the tank no longer than 24 hours. This can be accomplished by installing baffles in the tank to encourage mixing or to create a one-way path through the tank. The tank also can be drawn down periodically.

Database Management

AFB water systems should develop a computer-based comprehensive database management system to record distribution system physical and maintenance data. This database will be helpful in determining candidate mains for rehabilitation and replacement program.

Control of Nutrients

After implementing all immediate and short-term programs outlined in Subsections 3.2.4 and 3.2.5, if biofilm growth in the distribution system still continues, controlling the levels of nutrients available for bacterial growth (AOC) should be considered.

The advantages of reduction of AOC in the finished water are biofilm growth reduction and reduction of chlorine consumption.

The following alternative treatments are recommended for AOC reduction in the finished water:

- Use of GAC filters.
- Use of mixed filters of GAC and sand.
- Biologically activated filters.

By reducing AOC levels to less than 100 µg/L, growth of coliform bacteria in distribution system biofilms can be reduced.

3.2.7 Summary

Biofilm supports coliform bacteria in the distribution system. A biofilm control strategy requires a thorough understanding of water quality changes in treatment and distribution. The BCE for AFB water systems should develop a biofilm control plan as outlined in this section. The biofilm

control plan is not only a plan to control biofilm growth but also to prevent formation of the growth.

AFB water systems should maintain an adequate treatment effluent disinfectant residual, implement a regular flushing program, and practice a good water main maintenance program to reduce the risk of biofilm. If a coliform problem in an AFB water system can be ruled out due to treatment failure or cross-connection and a properly designed biofilm control is in place, the AFB can apply to the state for a variance.

SECTION 4

COMPREHENSIVE MAINTENANCE PROGRAM

This section of the report presents a systematic methodology to develop a comprehensive maintenance program for the purpose of improving general water quality in distribution systems.

4.1 SYSTEMATIC METHODOLOGY

All AFB water systems should develop systematic methodologies and plans to improve water quality in distribution by improving facility performance and operations. These improvements will be necessary to achieve distribution system water quality objectives and goals to provide safe and good quality service to customers by minimizing aesthetic water quality complaints by customers and without violating water quality rules. This can be achieved by developing and implementing a systematic program with the goals of reduction of both customer complaints and water quality rule violations.

Figure 4-1 provides a flow diagram describing a general methodology for evaluating distribution system water quality performance. This methodology has six steps, which are described in the following paragraphs.

Step I involves the evaluation of existing and historical information. This includes water quality monitoring data as required by the SDWA and customer complaint data. This data review and evaluation should be conducted with the objective of isolating the historical problem area(s) and determining the potential causes of the problem. In this step, the water distribution system should be divided into zones with similar characteristics, such as pressure or water source. The data analysis will include evaluation of historical water quality monitoring data, customer complaint data, characteristics of historical and currently active water sources, water main material (such as unlined cast-iron, ductile iron), dead ends, low flow and high retention area and flushing data. Adverse water quality monitoring data and customer complaint data should be plotted in the distribution system zone under consideration along with other information regarding characteristics of the distribution system zone, such as unlined cast-iron mains, dead ends, low flow areas, construction activities, and flushing frequency. When all of this information is shown on the map, a pattern of the problem may emerge and causes of the problem may be indicated.

Step II involves development of a long-term distribution system water quality performance improvement plan. This plan should be a part of the overall water distribution system performance improvement plan and will provide the justification for long-term and short-term water quality improvement programs and their associated investment and will help in developing

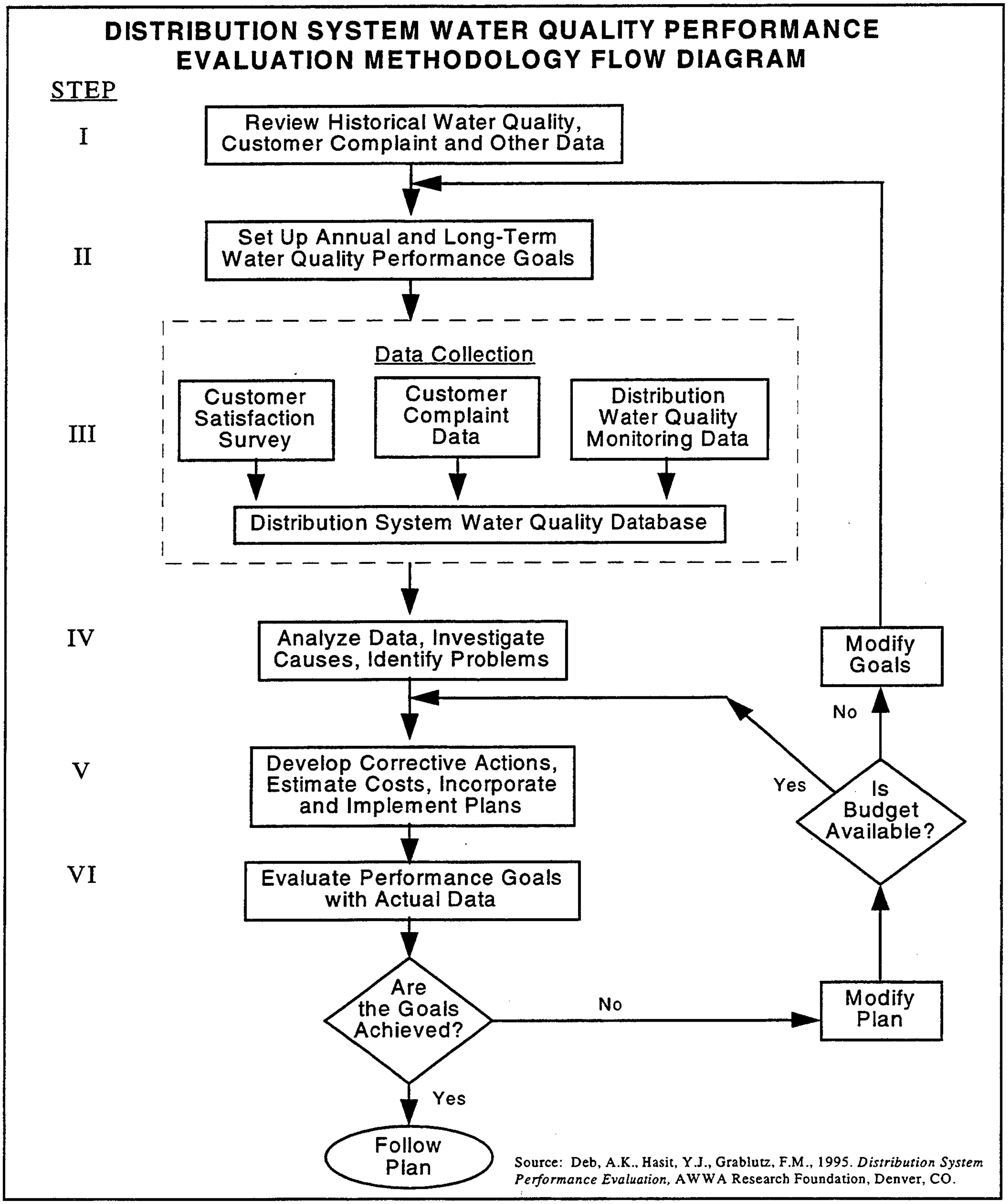

DISTRIBUTION SYSTEM WATER QUALITY PERFORMANCE EVALUATION METHODOLOGY FLOW DIAGRAM
STEP
I
Review Historical Water Quality, Customer Complaint and Other Data
II
Set Up Annual and Long-Term Water Quality Performance Goals
Data Collection
III
Customer Satisfaction Survey
Customer Complaint Data
Distribution Water Quality Monitoring Data
Distribution System Water Quality Database
IV
Analyze Data, Investigate Causes, Identify Problems
Modify Goals
No
V
Develop Corrective Actions, Estimate Costs, Incorporate and Implement Plans
Yes
Is Budget Available?
VI
Evaluate Performance Goals with Actual Data
Are the Goals Achieved?
No
Modify Plan
Yes
Follow Plan
Source: Deb, A.K., Hasit, Y.J., Grablutz, F.M., 1995. *Distribution System Performance Evaluation*, AWWA Research Foundation, Denver, CO.

FIGURE 4-1

financial planning. The plan should be reviewed every year and updated every 5 years. Actual improvement in performance of the distribution system as a result of implementation of a planned project should be documented and used in revising the plan.

The goals of the plan should be to comply with regulations and to provide specified quality service to its customers. The quality service should meet the requirements of the SDWA and other state and local regulations.

Step III involves the development of a distribution water quality database management system. In order to use all past, present, and future customer complaints data, water quality monitoring data related to characteristics of water sources, water mains, dead ends and other appropriate parameters for the purpose of identifying the cause(s) of problems and development of solutions in a cost-effective way, it is necessary to develop a distribution water quality database management system. This database should be developed on a distribution zone-by-zone basis and should contain geographical location, time, and dates, as well as water quality or complaint data. All available historical information on direct (i.e., bacteriological, aesthetic, and contaminant concentration) and indirect (i.e., residence time, system pressure, tuberculation, and customer complaints) water quality parameters should be incorporated in the database. If a geographic information system (GIS) for the water distribution system is available, this database should then be integrated with the GIS system. Integration of the database with the GIS system will provide flexibility for analysis of data and maximize the opportunity for quick resolution of a water quality problem.

Step IV involves analysis of historical data and data collected in direct response to a problem. This would include data collected in response to a customer complaint or in response to a water quality rule violation. The objective of this step is to reassess historical data and information along with newly collected data to identify causes of the problem. After initial analysis of the problem, it may be necessary to collect additional data. A plan should be developed to systematically collect these additional data. For example, additional samples may be required to identify a water quality problem as local or regional in character. If the problem is the water source, the affected area will be the entire area supplied by the same source. The contaminant concentration trend will be a reduction in average concentration as the water proceeds from treatment plant source to the ends of the distribution system. If the problem is localized due to dead ends, low flows in local mains or local unlined cast-iron mains, the average concentration of contaminants will increase from source towards the location of the problem. The causes of the problem may be determined to be associated with local stagnation of flow and or unlined cast-iron main.

Another tool to identify causes of water quality problems in the distribution system is the use of one of the commonly available distribution system water quality models. During the last 5 years, a number of computer based models have been developed to simulate behavior of contaminants in the distribution system. These models have a demonstrated record of success in identifying sources of contaminants, assessing various operational and design options to improve the water quality, and assisting in the design of a proper water quality sampling program.

Unlined tuberculated water mains with a high potential for biofilm growth exerting high chlorine demand cause low residual chlorine. These models can be used to identify water mains with high decay coefficients or high pipe wall chlorine demands causing low residual chlorine in the distribution system.

Step V is the development of corrective measures. It has been discussed in Step IV that two principal causes of water quality deterioration in the distribution mains are high residence time (stagnation of water) and formation of biofilm on pipe walls creating high chlorine demands. These situations may occur due to the following:

- Low flow areas with high residence time.
- Dead ends with high residence time.
- Unlined cast-iron mains with tuberculation.
- High concentration of AOC in water.

The following corrective measures should be used to improve water quality in the distribution system.

- Conduct routine flushing/emergency or corrective measures.
- Design and operate the distribution system by minimizing residence time.
- Improve disinfection (increase residual chlorine, use chloramines).
- Prevent tuberculation and corrosion of water mains (cleaning and lining, replacement of water mains).
- Reduce AOC at the treatment plant.
- Optimize corrosion control treatment to reduce corrosion rates of water mains and service lines.
- Minimize water main breaks.

Step VI is the evaluation of performance goals. The results of implementing a comprehensive maintenance program for improvement of distribution water quality should be monitored in order to analyze the effectiveness of the program.

Actual improvement achieved should then be compared with the distribution water quality performance goals. This plan should be reviewed annually against actual performance. If short-term performance goals are not achieved, the strategic plan should be modified accordingly.

SECTION 5

TYNDALL AIR FORCE BASE WATER SYSTEM — A CASE STUDY

5.1 TYNDALL AIR FORCE BASE WATER DISTRIBUTION SYSTEM

The Tyndall Air Force Base (TAFB) water distribution network consists of approximately 35 miles of pipe, ranging in size from 2-inch to 16-inch diameter mains. Pipe materials include unlined cast iron, asbestos cement, transite, and PVC. A schematic diagram of the TAFB water distribution system is shown in Figure 5-1. All of the water is supplied by Bay County Regional Water Authority through one meter at the foot of the DuPont Bridge. Average Daily Flow (ADF), according to Bay County's meter records, for the period 19 June 1994 through 31 May 1995 was 506 gpm or 0.73 million gallons per day (mgd). Average monthly demands ranged between 0.53 mgd and 1.07 mgd. Maximum and minimum daily demands were 1.39 mgd and 0.35 mgd, respectively. The contract between TAFB and Bay County requires Bay County to supply up to three million gallons per day at a minimum pressure of 60 psig and a desired pressure of 80 psig between 2200 hours and 0600 hours for purposes of filling the three elevated storage tanks on base.

There are no pumps or storage tanks on the Bay County system between the water treatment plant and the base that affect the TAFB system. At TAFB, there are three elevated water storage tanks that handle peak demands. Two of the tanks are 250,000 gallons each and one is 150,000 gallons. There is a height and elevation difference between the two different size tanks. The altitude valve settings for the two 250,000-gallon tanks are 137.5 feet. The altitude valve setting for the 150,000-gallon tank is 120.7 feet. TAFB recently completed a full inspection of these three tanks. These tanks were not maintained on time; as a result, some pitting developed inside the tanks. Refilling of storage tanks takes place at night. Operation of the storage tanks indicates the 24-hour fluctuations of water levels in storage tanks. The daily refilling operation will reduce stagnation of water in these tanks. However, water elevations in each storage tank should be monitored.

The TAFB water system also has two deluge systems to serve fire flow requirements for the flightline hangars. Water in the deluge system is stagnant for long times, which may result in a source of water quality problems. After evaluation of the piping in the deluge systems area, it has been found by line maintenance personnel that the services to both systems are through one service connection to the water system with the appropriate backflow preventers. These backflow preventers should be checked and monitored regularly to avoid any backflow from the deluge system. Additionally, at the TAFB meter, there is a pressure-reducing valve. The

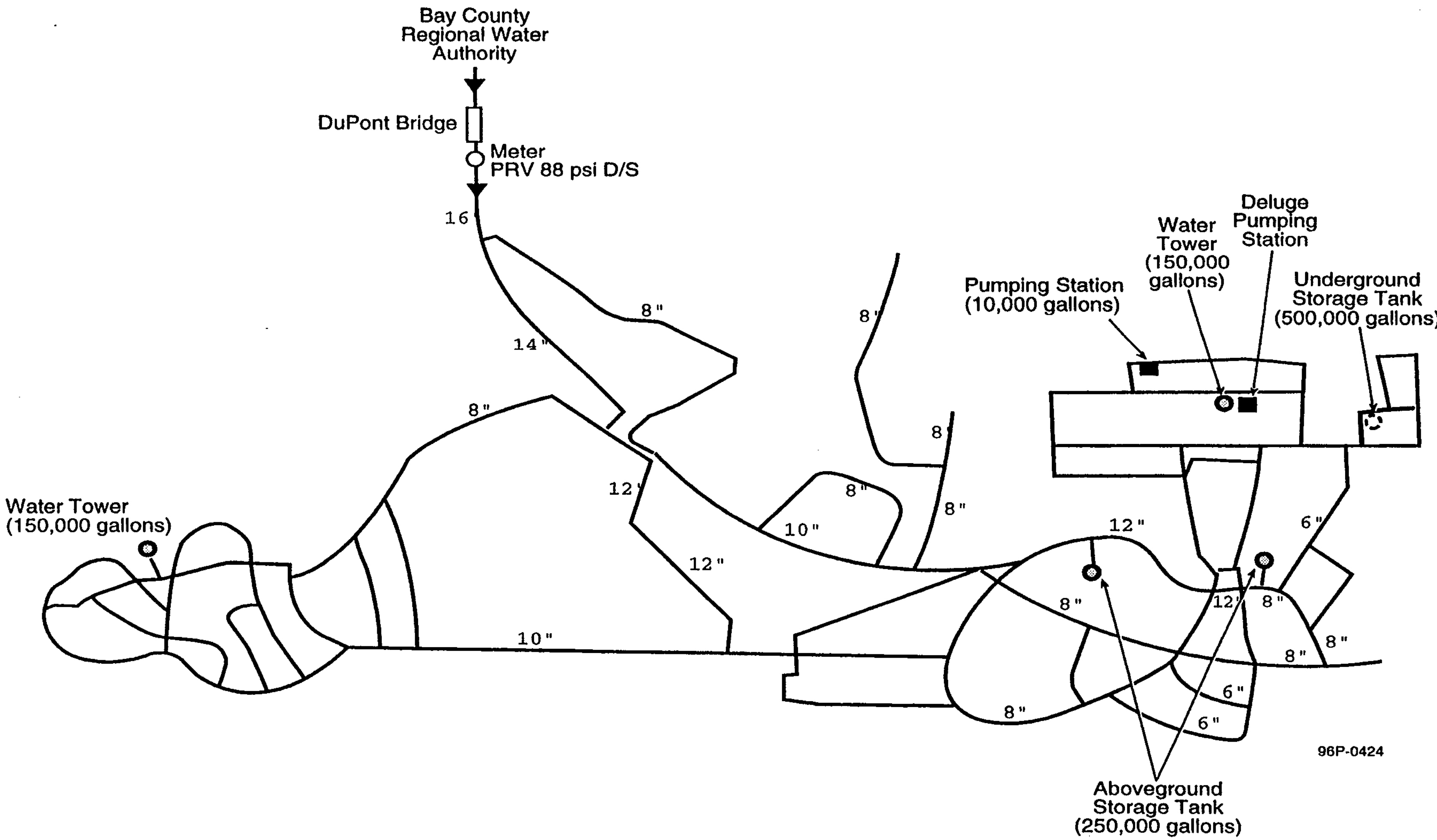


FIGURE 5-1 TYNDALL AIR FORCE BASE (TAFB) WATER DISTRIBUTION SYSTEM SCHEMATIC DIAGRAM

downstream pressure (TAFB side) was set at 88 psi, while upstream pressures ranged from 95 to 105 psi (Bay County side).

Most of the water mains in the TAFB distribution system are old, unlined cast-iron pipes, with the exception of the asbestos cement pipe that parallels Beacon Beach Road to Wood Manor Housing, and the PVC pipe between the wastewater treatment plant and 1800 Area, and the main that reaches the 6000 Area. A plot of recent water main break locations and the locations of TCR violations on the TAFB distribution map indicates that most of the water main breaks and water quality violations occurred in the old cast-iron water main area. A field study on evaluation of the C-values of water mains indicates that some of the old cast iron water mains have very low C-values, indicating interior tuberculation of pipes. Again, these tuberculations provide a large surface area and present good places for biofilm growths.

TAFB is experiencing some problems in maintaining water mains and is currently conducting a study to develop a distribution system hydraulic model and to identify the need for replacement or rehabilitation of water mains. Preliminary results of the study indicate that some of the water mains on the base are in bad hydraulic condition with a Hazen Williams Coefficient C-value as low as 25. A normal water main should have a C-value of about 100.

Fill rates to the TAFB tanks are limited due to inadequate supply pressures as well as the anticipated tuberculated hydraulic conditions of mains leading to these tanks.

The BEE maintains 20 sampling and monitoring locations in the TAFB distribution system. However, sampling and monitoring location maps were not available. Chlorine residual and pH are monitored 3 days per week (Monday, Tuesday, and Wednesday). Bacteriological sampling is conducted once per month at each of the 20 locations.

5.2 HISTORY OF COLIFORM VIOLATION AT TAFB

5.2.1 Overview

Coliform bacteria began to appear in the TAFB water distribution system immediately following tropical storm Alberto during the 1994 Fourth of July weekend. It is thought that the high winds and rain compromised the treatment efficiency of the Bay County Regional Water Authority (BCRWA) water treatment facility, resulting in a reduction in water quality. The BCRWA notified their customers of the reduced water quality, and TAFB informed the base population on 29 July 1994 that the water should be boiled prior to consumption. The State of Florida subsequently lifted the boil water notice on 5 August 1994, following several negative test results. It was not clear from available information whether the BEE followed TCR requirements of sampling and reporting and whether BEE had an action plan in place to comply with TCR.

During the July-August 1994 period, coliform monitoring at approximately 50 locations showed numerous positive samples across the entire industrial and residential portions of the base. Base

staff also identified zero residual chlorine at numerous bacteriological sampling points as early as 6 June 1994. Following this time period, continued coliform monitoring identified several areas that continue to test positive for coliform. Table 5-1 shows a summary of zero residual chlorine and positive coliform data during this period. The data indicate that zero residual chlorine was measured continuously prior to positive measurements of total coliform and fecal coliform at the following locations: Wood Manor Fire Department, Officers Club, Building 1125, Golf Course, Youth Center, NCO Club, Beacon Beach and Shoal Point shoppettes. Apparently, no action was taken initially to increase the residual chlorine at these locations in the distribution system that resulted in positive total and fecal coliform results in July and August 1994. Since zero residual chlorine is an early indication of a potential coliform problem, the BEE should inform the BCE to conduct flushing of water mains in the area. BCE should also request BCRWA 700 higher dosage of chlorine at the base.

TAFB BEE, in conjunction with staff from the AL, have documented this coliform violation incident and their response in a document entitled *Draft Field Report, Investigation of Bacteriological Contamination Problem at Tyndall AFB, Florida*, dated 29 August 1994.

5.2.2 Findings, Conclusions, and Recommendations

As a part of the scope of work for this project, the WESTON Project Manager visited TAFB and, with the help of the base CE and BEE, obtained information relating to the violation of TCR. The following are the findings:

1. Water purchased from Bay County Regional Water Authority during the July-August 1994 contained no coliforms.

   WESTON's review of the Bay County Drinking Water Bacteriological Analysis Reports for the period 1 July 1994 through 28 April 1995, confirms that this continues to be true for the period following the July-August 1994 incident. These reports routinely present sample results at 7th Street, 17th Street, TAFB (DuPont Bridge), and the Navy Base West Gate. Review of the reports indicates that no chlorine residual was detected on 5 July 1994 at the Navy Base and that total coliforms were detected and confirmed at the 7th Street tap on 13 April 1995. Fecal coliform was not confirmed. Chlorine residuals at the DuPont Bridge are consistently above 1.0 mg/L, except for four incidents during July 1994 when chlorine residuals were between 0.6 and 0.8 mg/L. An additional low chlorine residual occurred during February 1995 and three others during April 1995. Residuals were 0.5 to 0.9 mg/L during these occurrences.

2. A biofilm was determined to be present. Analysis of a sample taken from the NCO Club shows presence of *Klebsiella* and *Escherichia coli*.

Table 5-1
History of Violations of TCR (Tyndall Air Force Base)
(July-August 1994)

Date Of Sampling	Locations of Sampling																		
	Officers Club	Wood Manor Fire	Youth Center	Golf Course	Bldg. 1125	Bay View #2377	9700 Area	Tyndal l Elem.	Beacon Beach 2598	Shoal Pt. Shoppette	Base Ops	Day Care	Weg. Bldg.	6000 Area	NCO Club	Bldg. 9725	Bldg. 9706	Bldg. 9733	Bldg. 1120
06/06/94	Cl_2 zero	Cl_2 zero	Cl_2 zero	Cl_2 zero	Cl_2 zero														
06/14/94							Cl_2 zero												
06/15/94						Cl_2 zero			Cl_2 TR										
06/20/94								Cl_2 zero			Cl_2 zero	Cl_2 zero	Cl_2 zero						
07/05/94			Cl_2 zero TC	Cl_2 zero TC		TC	Cl_2 TR		Cl_2 zero		TC	Cl_2 zero	Cl_2 zero						
07/06/94									TC		Cl_2 zero				Cl_2 TR				
07/18/94					Cl_2 zero	Cl_2 zero								Cl_2 zero					
07/20/94							Cl_2 zero									Cl_2 zero	Cl_2 zero	Cl_2 zero	
07/26/94	TC FC	TC FC	TC	TC FC					TC FC	TC FC					TC FC				TC FC
07/27/94		Cl_2 zero	Cl_2 zero	Cl_2 zero TC	Cl_2 zero TC					Cl_2 zero					Cl_2 zero				Cl_2 zero
07/29/94	TC	Cl_2 zero TC	Cl_2 zero TC	Cl_2 zero TC					TC Cl_2 zero	TC Cl_2 zero					Cl_2 zero TC				
07/30/94		Cl_2 zero		Cl_2 zero						Cl_2 zero					TC				Cl_2 zero
07/31/94	TC	Cl_2 zero	Cl_2 zero	Cl_2 zero					TC	Cl_2 zero TC					TC				TC Cl_2 zero
08/01/94	TC	TC Cl_2 zero	Cl_2 zero	Cl_2 zero TC					TC	Cl_2 zero									Cl_2 zero TC

NOTES:
Cl_2 zero = Chlorine Residual Zero   FC = Fecal Coliform Positive
Cl_2 TR = Chlorine Residual Trace   TC = Total Coliform Positive

3. Coliform positive samples with the highest number of colonies were from areas with low chlorine residual, dead-end lines and low demand (i.e., inactive buildings).

4. Nondetectable chlorine residuals were noted at sampling locations where low flow conditions exist (i.e., dead-end lines and inactive buildings).

The report concluded that reduced water quality resulted from tropical storm Alberto.

The AL report recommended the establishment of systemwide maintenance procedures to minimize biofilm growth. These procedures include implementation of a systematic flushing program, completion of the cross-connection survey, inspection and monitoring of storage tanks, bacteriological sampling at B5002 (BCRWA supply line) and at various locations on water distribution system mains, constructing a chlorine monitoring and booster station at B5002, and performing a basewide sanitary survey.

5.2.3 Main Breaks

A review of the Water Distribution Main History File shows the creation and closing of 30 incidents during the period from 18 May 1994 through 5 October 1994. Fifteen of these had sufficient information to locate them on the maps of the distribution system provided to WESTON. Seven had insufficient location data, and two could not be located on the maps provided. The remaining six records concerned line spotting activities (3), hydrant flushing (1), and hydrant and vacuum breaker repairs (2).

Review of the Sanitary Sewage Main History File for roughly the same time period shows the creation and closing of seven records. However, only two of these concerned broken sewer lines. It is noted that one of these contained insufficient location data. The other concerned a broken sewer line behind B1580, which was repaired between 27 September and 3 October 1994. The remaining five records were for mechanical and electrical repairs not involving the spilling of sewage.

The records do not show occurrence of both water main and sewer main breaks in close proximity. However, a review of the bacteriological sampling data shows positive total coliforms at the Officers Club (B1454), which is located approximately 1,600 feet from the sewer main break, for both the July-August 1994 and March-April 1995 periods. Positive coliforms also were observed at B1580 and B1582 during the March-April 1995 period.

5.2.4 Test Case Application of Corrective Action Plan

In this section, the TAFB water system has been used as a test case application of the corrective action plan developed in Subsection 3.2

TAFB experienced zero residual chlorine, high heterotrophic bacteria followed by coliform bacteria during July-August 1994. Measurement of inlet residual chlorine and bacteriological analysis showed no indication of bacteriological problems at the inlet to the distribution system. This indicates positive coliform in the distribution system may be to cross-connection or due to biofilm growth.

Typical characteristics of biofilm growth, as outlined in Section 3, such as seasonality, stagnant water, occurrence of heterotrophic bacteria and zero residual disinfectant prior to occurrence of positive coliform and AOC concentration levels, as found in TAFB water systems during July-August 1994, appear to be ideal conditions for biofilm growth. The average DOC concentration in TAFB water systems during February to May 1995 was found to be 3.1 mg/L. TAFB DOC data for 1994 were not available. Assuming 5% of DOC will be AOC, AOC concentration of TAFB water will be more than 150 µg/L. It is recommended that AOC should be kept within 100 µg/L for control of biofilm.

From this analysis, it appears that there is a high potential that coliform at the TAFB water system was of biofilm origin. AL visited TAFB in August 1994 and recommended the following:

- Construction of a chlorine monitoring and booster station at B5002 and boosting chlorine dosage.
- Flushing the affected water mains and developing a systematic flushing program.
- Completion of cross-connection survey.
- Inspection and monitoring of storage tanks.
- Bacteriological sampling.

All AL recommendations are also part of the action plan developed in Section 3 of this report. TAFB implemented all the AL recommendations.

Regarding long-term (1 to 5 years) planning, TAFB should develop and implement the following:

- Develop an unlined cast-iron water main rehabilitation (cleaning and lining) and replacement plan.
- Develop a distribution system maintenance database program.
- Monitor AOC of water entering TAFB distribution system.
- Conduct a sanitary survey of TAFB water system.
- Complete the hydraulic modeling of the distribution system.

- Consider implementation of a chlorination system at the booster station B5002 if zero residual chlorine data are obtained even after boosting the chlorine dosage.

- Continue to implement the flushing program two times per year (spring and fall).

- Develop and implement immediate action plans for future coliform bacteria occurrence.

- Evaluate criteria in Table 3-2 and apply for variance, if necessary.

- Make staff available to conduct these tasks.

It appears that TAFB BCE has a significant shortage of staff and funding to develop and implement these plans. Therefore, action should be taken to make qualified staff available to implement these programs.

SECTION 6

INFORMATION RESOURCES

Each AFB should have the following documents for reference:

Safe Drinking Water Act (Public Law 95-190 Section 1447).

Air Force Regulations

- MIL-HDBK-1164, Maintenance and Operation of Water Supply, Treatment, and Distribution Systems. (publication Apr 97)
- AFI 48-119, Environmental Pollution Monitoring.
- AFI 32-7006, Environmental Program in Foreign Countries.
- AFM 88-10 Volume 1, Water Supply Sources and General Considerations; Volume 3, Water Supply, Water Treatment; Volume 4, Water Supply, Water Storage; and Volume 5, Water Supply, Water Distribution.
- AFI 32-1067, Water Systems.
- AFSOH Std. 48-6.

Optional references:

Deb, A.K., H.J. Hasit, and F.M. Grablutz. 1995. *Distribution System Performance Evaluation*, AWWA Research Foundation Report.

LeChevallier, M.W., B.H. Olson, and G.A. McFeters. 1990. *Assessing and Controlling Bacterial Regrowth in Distribution Systems*, AWWA Research Foundation Report.

REFERENCES

ASTM (American Society for Testing and Materials). 1993. *Standard Methods for the Examination of Water and Wastewater*, 18th Edition.

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AWWA. *Total Coliforms. A Working Explanation of the Total Coliforms Rule*. SDWA Series.

EA Engineering, Science, and Technology, Inc. 1995. *Safe Drinking Water Management Action Plan for Seymour Johnson AFB*.

LeChevallier, M.W., C.D. Lowry, and R.G. Lee. 1990. Disinfection of biofilms in a model distribution system. *J. AWWA* 82(7).

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McCabe, L., J.M. Symons, R.D. Lee, and G.G. Robeck. 1970. Study of Community Water Supply Systems. *J. AWWA* 62(11).

Van der Kooij, D., A. Visser, and W.A.M. Hijnen. 1982. Determining the concentration of easily assimable organic carbon in drinking water. *J. AWWA* 74(10).

Olin Corporation. 1971. *Hypochlorination of Water*. Stanford, CT.

APPENDIX A

GLOSSARY OF TERMS

Source: EA Engineering, Science, and Technology, Inc. 1995.

Safe Drinking Water Management Action Plan for Seymour Johnson AFB.

APPENDIX A

GLOSSARY OF TERMS

Action level - the concentration of lead or copper in water specified in 40 CFR 141.80(c) that determines, in some cases, the treatment requirements that a water system is required to complete.

Assimable organic carbon (AOC) - the fraction of dissolved organic carbon in water that bacteria can use for growth.

Best available technology (BAT) - the best technology, treatment techniques, or other means that the administrator finds, after examination for efficacy under field conditions and not solely under laboratory conditions, are available (taking cost into consideration). For the purposes of setting MCLs for synthetic organic compounds, any BAT must be at least as effective as granular activated carbon.

Coagulation - a process using coagulant chemicals and mixing by which colloidal and suspended materials are destabilized and agglomerated into flocs.

Community water system (CWS) - a public water system that serves at least 15 service connections used by year-round residents or regularly serves at least 25 year-round residents.

Compliance cycle - the 9-year calendar-year cycle during which public water systems must monitor. Each compliance cycle consists of three 3-year compliance periods. The first calendar year cycle begins 1 January 1993 and ends 31 December 2001; the second begins 1 January 2002 and ends 31 December 2010; the third begins 1 January 2011 and ends 31 December 2019.

Compliance period - a 3-year calendar-year period within a compliance cycle. Each compliance cycle has three 3-year compliance periods. Within the first compliance cycle, the first compliance period runs from 1 January 1993 to 31 December 1995; the second from 1 January 1996 to 31 December 1998; the third from 1 January 1999 to 31 December 2001.

Confluent growth - a continuous bacterial growth covering the entire filtration area of a membrane filter, or a portion thereof, in which bacterial colonies are not discrete.

Contaminant - any physical, chemical, biological, or radiological substance or matter in water.

Conventional filtration treatment - a series of processes including coagulation, flocculation, sedimentation, and filtration resulting in substantial particulate removal.

APPENDIX A

GLOSSARY OF TERMS
(Continued)

Corrosion inhibitor - a substance capable of reducing the corrosivity of water toward metal plumbing materials, especially lead and copper, by forming a protective film on the interior surface of those materials.

CT or CTcalc - the product of "residual disinfectant concentration" (C) in mg/L determined before or at the first customer, and the corresponding "disinfectant contact time" (T) in minutes, i.e., (CxT).

Diatomaceous earth filtration - a process resulting in substantial particulate removal in which (1) a precoat cake of diatomaceous earth filter media is deposited on a support membrane (septum), and (2) while the water is filtered by passing through the cake on the septum, additional filter media known as body feed is continuously added to the feed water to maintain the permeability of the filter cake.

Direct filtration - a series of processes including coagulation and filtration, but excluding sedimentation, resulting in substantial particulate removal.

Disinfectant - any oxidant, including but not limited to chlorine, chlorine dioxide, chloramines, and ozone added to water in any part of the treatment or distribution process, that is intended to kill or inactivate pathogenic microorganisms.

Disinfectant contact time (T in CT calculations) - the time in minutes that it takes for water to move from the point of disinfectant application or the previous point of disinfectant residual measurement to a point before or at the point where residual disinfectant concentration (C) is measured; T is the time in minutes that it takes for water to move from the point of disinfectant application to a point before or at the point where residual disinfectant concentration (C) is measured.

Disinfection - a process that inactivates pathogenic organisms in water by chemical oxidants or equivalent agents.

Domestic or other nondistribution system plumbing problem - a coliform contamination problem in a public water system with more than one service connection that is limited to the specific service connection from which the coliform-positive sample was taken.

Dose equivalent - the product of the absorbed dose from ionizing radiation and such factors as account for differences in biological effectiveness due to the type of radiation and its distribution in the body as specified by the International Commission on Radiological Units and Measurements (ICRU).

APPENDIX A

GLOSSARY OF TERMS
(Continued)

Effective corrosion inhibitor residual - a concentration sufficient to form a passivating film on the interior walls of a pipe.

Filtration - a process for removing particulate matter from water by passage through porous media.

First draw sample - a 1-liter sample of tap water, collected in accordance with 40 CFR 141.86(b)(2), that has been standing in plumbing pipes at least 6 hours and is collected without flushing the tap.

Flocculation - a process to enhance agglomeration or collection of smaller floc particles into larger, more easily settleable particles through gentle stirring by hydraulic or mechanical means.

Gross alpha particle activity - the total radioactivity due to alpha particle emission as inferred from measurements on a dry sample.

Gross beta particle activity - the total radioactivity due to beta particle emission as inferred from measurements on a dry sample.

Groundwater under the direct influence of surface water - any water beneath the surface of the ground with (1) significant occurrence of insects or other macroorganisms, algae, or large-diameter pathogens such as *Giardia lamblia*, or (2) significant and relatively rapid shifts in water characteristics such as turbidity, temperature, conductivity, or pH that closely correlate to climatological or surface water conditions.

Halogen - one of the chemical elements chlorine, bromine or iodine.

Haloacetic acids (HAAs) - a member of the family of halogenated derivatives of acetic acid.

Initial compliance period - the first full 3-year compliance period which begins at least 18 months after promulgation, except for contaminants listed at 40 CFR 141.61(a)(19) - (21), (c)(19) - (33), and 40 CFR 141.62 (b)(11) - (15), initial compliance period means the first full 3-year compliance period after promulgation for systems with 150 or more service connections (January 1993 - December 1995), and first full 3-year compliance period after the effective date of the regulation (January 1996 - December 1998) for systems having fewer than 150 service connections.

Large water system - a water system that serves more than 50,000 persons.

APPENDIX A

GLOSSARY OF TERMS
(Continued)

Lead service line - a service line made of lead that connects the water main to the building inlet and any lead pigtail, gooseneck, or other fitting that is connected to such lead line.

Legionella - a genus of bacteria, some species of which have caused a type of pneumonia called Legionnaires Disease.

Man-made beta particle and photon emitters - all radionuclides emitting beta particles and/or photons listed in *Maximum Permissible Body Burdens and Maximum Permissible Concentration of Radionuclides in Air or Water for Occupational Exposure,* NBS Handbook 69, except the daughter products of thorium-232, uranium-235, and uranium-238.

Maximum contaminant level (MCL) - the maximum permissible level of a contaminant in water that is delivered to any user of a public water system.

Maximum contaminant level goal (MCLG) - the maximum level of a contaminant in drinking water at which no known or anticipated adverse effect on the health or persons would occur, and which allows an adequate margin of safety. Maximum contaminant level goals are nonenforceable health goals.

Maximum total trihalomethane potential (MTP) - the maximum concentration of total trihalomethanes produced in a given water containing a disinfectant residual after 7 days at a temperature of 25 °C or above.

Medium-size water system - a water system that serves greater than 3,300 and fewer than or equal to 50,000 persons.

Near the first service connection - at one of the 20% of all service connections in the entire system that are nearest the water supply treatment facility, as measured by water transport facility, as measured by water transport time within the distribution system.

Noncommunity water system (NCWS) - a public water system that is not a community water system.

Nonpotable water - water that is not considered to be safe for human consumption.

Nontransient noncommunity water system (NTNCWS) - a public water system that is not a community water system and that regularly serves at least 25 of the same persons over 6 months per year.

APPENDIX A

GLOSSARY OF TERMS
(Continued)

Optimal corrosion control treatment - the corrosion control treatment that minimizes the lead and copper concentrations at users' taps while ensuring that the treatment does not cause the water system to violate any national primary drinking water regulations.

Performance evaluation sample - a reference sample provided to a laboratory for the purpose of demonstrating that the laboratory can successfully analyze the sample within limits of performance specified by the agency. The true value of the concentration of the reference material is unknown to the laboratory at the time of the analysis.

Person - an individual; corporation; company; association; partnership; municipality; or state, federal, or tribal agency.

Picocurie (pCi) - the quantity of radioactive material producing 2.22 nuclear transformations per minute.

Point of disinfectant application - the point where the disinfectant is applied and water downstream of that point is not subject to recontamination by surface water runoff.

Point-of-entry treatment device - a treatment device applied to the drinking water entering a house or building for the purpose of reducing contaminants in the drinking water distributed throughout the house or building.

Point-of-use treatment device - a treatment device applied to a single tap used for the purpose of reducing contaminants in drinking water at that one tap.

Potable water - water that is considered fit to drink by humans.

Public water system (PWS) - a system for the provision to the public of piped water for human consumption, if such system has at least 15 service connections or regularly serves an average of at least 25 individuals daily at least 60 days out of the year. Such term includes (1) any collection, treatment, storage, and distribution facilities under control of the operator of such system and used primarily in connection with such system, and (2) any collection or pretreatment storage facilities not under such control that are used primarily in connection with such system. A public water system is either a community water system or a noncommunity water system.

Rem - the unit of dosage equivalent from ionizing radiation to the total body or any internal organ or organ system. A millirem (mrem) is 1/1000 of a rem.

APPENDIX A

GLOSSARY OF TERMS
(Continued)

Repeat compliance period - any subsequent compliance period after the initial compliance period.

Residual disinfectant concentration (C in CT calculations) - the concentration of disinfectant measured in mg/L in a representative sample of water.

Sanitary survey - an on-site review of the water source, facilities, equipment, operation and maintenance of a public water system for the purpose of evaluating the adequacy of such source, facilities, equipment, operation and maintenance for producing and distributing safe drinking water.

Sedimentation - a process for removal of solids before filtration by gravity or separation.

Service line sample - a 1-liter sample of water collected in accordance with 40 CFR 141.86(b)(3) that has been standing for at least 6 hours in a service line.

Single family structure - a building constructed as a single-family residence that is currently used as either a residence or a place of business.

Slow sand filtration - a process involving passage of raw water through a bed of sand at low velocity (generally less than 0.4 m/h) resulting in substantial particulate removal by physical and biological mechanisms.

Small water system - a water system that serves 3,300 fewer persons.

Standard sample - the aliquot of finished drinking water that is examined for the presence of coliform bacteria.

State - the agency of the state or tribal government that has jurisdiction over public water systems. During any period when a state or tribal government does not have primary enforcement responsibility pursuant to section 1413 of the Act, the term state means the Regional Administrator, U.S. Environmental Protection Agency.

Secondary maximum contaminant level (SMCL) - unenforceable standards promulgated for compounds that affect the taste, odor, color, and certain other non-aesthetic characteristics of drinking water.

Supplier of water - any person who owns or operates a public water system.

Surface water - all water that is open to the atmosphere and subject to surface runoff.

APPENDIX A

GLOSSARY OF TERMS
(Continued)

System with a single service connection - a system that supplies drinking water to consumers via a single service line.

Too numerous to count - the total number of bacterial colonies exceeds 200 on a 47-mm diameter membrane filter used for coliform detection.

Total trihalomethanes (TTHM) - the sum of the concentration in milligrams per liter of the trihalomethane compounds (trichloromethane [chloroform], dibromochloromethane, bromodichloromethane, and tribromomethane [bromoform]), rounded to two significant figures.

Transient noncommunity water system (TWS) - a noncommunity water system that does not regularly serve at least 25 of the same persons over 6 months per year.

Trihalomethane (THM) - one of the family of organic compounds, named as derivatives of methane, wherein three of the four hydrogen atoms in methane are each substituted by a halogen atom in the molecular structure.

Virus - a virus of fecal origin that is infectious to humans by waterborne transmission.

Waterborne disease outbreak - the significant occurrence of acute infectious illness, epidemiologically associated with the ingestion of water from a public water system that is deficient in treatment, as determined by the appropriate local or state agency.

APPENDIX B

SDWA CONTAMINANTS

Source: EA Engineering, Science, and Technology, Inc. 1995.

Safe Drinking Water Management Action Plan for Seymour Johnson AFB.

APPENDIX B

SDWA CONTAMINANTS

Phase I

Regulated Contaminants

benzene	carbon tetrachloride
para-dichlorobenzene	1,2-dichloroethane
1,1-dichloroethylene	1,1,1-trichloroethane
trichloroethylene	vinyl chloride

Contaminants to be Monitored

To be Monitored by all Systems	Monitor Only if System is Known to be Vulnerable	Monitor at State's Discretion
bromobenzene	ethylene dibromide	bromochloromethane
bromodichloromethane	1,2-dibromo-3-	n-butylbenzene
bromoform	chloropropane	dichlorodifluoromethane
bromomethane		fluorotrichloromethane
chlorobenzene		hexachlorobutadiene
chlorodibromomethane		isopropylbenzene
chloroethane		p-isopropyltoluene
o-chlorotoluene		napthalene
p-chlorotoluene		n-propylbenzene
dibromomethane		sec-butylbenzene
m-dichlorobenzene		tert-butylbenzene
dichloromethane		1,2,3-trichlorobenzene
1,1-dichloroethane		1,2,4-trichlorobenzene
1,3-dichloropropane		1,2,4-trimethylbenzene
2,2-dichloropropane		1,3,5-trimethylbenzene
1,1-dichloropropene		
1,3-dichloropropene		
1,1,1,2-tetrachlorethane		
1,1,2,2-tetrachloroethane		
1,1,2-trichloropropane		

APPENDIX B

SDWA CONTAMINANTS
(Continued)

Phase II

Regulated Contaminants

Inorganics	Volatiles	Pesticides, PCBs
asbestos	cis-1,2-dichloroethylene	alochlor
barium	1,2-dichloropropane	aldicarb*
cadmium	ethylbenzene	aldicarb sulfone*
chromium	monochlorobenzene	aldicarb sulfoxide*
mercury	o-dichlorobenzene	atrazine
nitrate	styrene	carbofuran
nitrite	tetrachloroethylene	chlordane
selenium	toluene	dibromochloropropane
	trans-1,2-dichloroethylene	2,4-D
	xylenes (total)	ethylene dibromide
		heptachlor
		heptachlor epoxide
		lindane
		methoxychlor
		PCBs
		pentachlorophenol
		toxaphene
		2,4,5-T (Silvex)

*MCL has been stayed.

Contaminants to be Monitored

aldrin	butachlor	carbaryl
dicamba	dieldrin	3-hydroxycarbofuran
methomyl	metolachlor	metribuzin
propachlor	simazine	

APPENDIX B

SDWA CONTAMINANTS
(Continued)

Treatment Technique

acrylamide	epichlorohydrin

Phase III (The Radionuclide Rule)

Regulated Contaminants (January 1996)

Radon-222	Radium-226
Radium-228	Uranium
Alpha emitters	Beta and photon emitters
Tritium*	Strontium-89*
Iodine-131*	Strontium-90*
Cesium-134*	Gamma & photon emitters*

Phase V

Regulated Contaminants

Inorganics	VOCs	Synthetic Organics	Pesticides
antimony	dichloromethane	benzo(a)pyrene	dalapon
beryllium	1,2,4-Trichlorobenzene	di(2-ethylhexyl)adipate	diquat
cyanide	1,1,2-Trichloroethane	di(2-ethylhexyl)phthalate	dinoseb
nickel		hexachlorocyclopentadien	endothal
thallium		hexachlorobenzene	endrin
sulfate*		2,3,7,8-TCDD (dioxin)	glyphosate
			oxamyl (vydate)
			picloram
			simazine

*No MCL has been established for sulfate.

APPENDIX B

SDWA CONTAMINANTS
(Continued)

Phase VIa

Phase VIa includes two proposed rules: the Disinfection/Disinfectant By-Product (D/DBP) Rule, and the Groundwater Disinfection Rule (GWDR).

Regulated Contaminants (Proposed)

Disinfectants	Inorganic By-Products	Organic By-Products
chlorine	chlorate	total trihalomethanes
chloramine	chlorite	chloroform
chlorine dioxide	bromate	bromoform
		bromodichloromethane
		dibromochloromethane
		trichloroacetic acid
		dichloroacetic acid
		total haloacetic acid
		chloral hydrate

Phase VIb

Regulated Contaminants (Proposed)

Inorganics	Organics	
boron	acifluorfen	acrylonitrile
manganese	bromomethane	cyanazine
molybdenum	2,4-dinitrotoluene2,6-dinitrotoluene	
zinc	ethylene thiourea	hexachlorobutabiene
	1,3-dichloropropene	1,3-trichloropropene